

THE SCIENTIFIC MONTHLY

Edited by
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WARE CATTELL

VOLUME LIII
JULY TO DECEMBER

NEW YORK
THE SCIENCE PRESS
1941

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THE SCIENCE PRESS

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PENNSYLVANIA

THE SCIENTIFIC MONTHLY

JULY, 1941

ZOOLOGICAL GARDENS. I.

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INTRODUCTION

TIME was when civilized cities had no electric light, no public baths, no public museums, nor libraries, but now these and many more are the common property of the people, who enjoy aids to the development of both body and mind undreamed of but a few years ago.

On the one hand we have our city golf courses which the weary factory worker may use, if he can afford the time and the rig; on the other hand, the symphony concert at cost price for those who prefer it to church; the city will fain feed all the desires of its citizens, to keep them in physical and mental health. Every city sees the advantages of parks; parks for air, for rest, for recreation, for music, for esthetic enjoyment of plants, grass and sky, for relief from the heat of mid-summer nights in cramped house space. Amongst the luxuries of the city park may be the opportunities for pleasure, wonderment, education and relief from care offered by the modern zoological park—no mere menageries or set of cages and unhappy inmates, but the real garden with its strange animals of all climes living as if at home but protected from enemies, well fed and happy in exercise, bringing forth abundantly after their kind, living longer than in their native wilds, often in large enclosures without bars, apparently free, but harmless to the lookers on who can see and photograph them with nothing between but the impassable moat.

In such zoological gardens one may also see the aquarium full of the fish like those one almost caught, see them as they can not be seen in pond or stream, not from the top nor from the flapping, dying, gasping result of hook fishing, but from the side as other fish see their friends, with all the strangeness of life under water free from weary weight and tired feet.

To be sure, many cities have no zoological gardens as yet, but zoological parks are no new fad of the present day, and their reason for existence lies very deep in the make-up of human life. At one time the possession of the king, the zoological collections have become the possession of the people, and this democratization will go on till every large collection of peoples will have its living library of plants and animals left over from the wild. The wild will be no more and all its wondrous life must perish utterly except what is, for a season, hoarded up in dry museums or brought under domestication for the direct physical good of man, or harbored and bred in zoological parks for the better spiritual growth of a civilization doomed to see the boundaries of the natural world narrowed more and more by man's destruction of so much that was there before he came and can not survive unless he will it.

How many zoological gardens are there to-day? More than one hundred of all sizes and grades of excellence.



Courtesy of Friede.

SIXTEENTH CENTURY PAINTING OF ANIMALS ENTERING THE ARK
BY GERADE DE JODE, FROM "THE BIBLE IN ART" BY CLIFTON HARRY.

Where are they found? In Japan, two; in China, none; in India, one; in Egypt, one; in Africa, three; in Australia, four; in New Zealand, one; in Italy, one; in Austria, one; in Hungary, one; in Switzerland, three; in France, four; in Germany, nineteen or so; in Holland, three; in Belgium, three; in Russia, two; in Great Britain, three; in Ireland, one; in Denmark, one; in Norway, one; in South America, four; in Canada, three; and in the United States, perhaps twenty.

Thus the far from ancient civilization of the United States has adopted these old world ways of pleasing the people and in some cases has arrived at the head of the procession.

In these days of imagined history underlying written records, when the "squatting place" ranks with the "tower of Babel" as well-known epochs in man's advance, it is not difficult to imagine how man and animal became first joined with bonds that still make him yearn for his old comrades of the

wilds. Man enters the present day zoological garden as necessary observer, a most essential inmate, but when man first appeared on earth he was but an interloper, a strange new inmate of the great garden where he encountered such strange fellow creatures. These he had to observe and study, for upon them depended his very existence and they were his first animate teachers to sharpen his wits, until he gained more and more dominion over them.

Many first men did not survive and many, very many, of his contemporary fellow animals did not survive, but some few men and animals continued on together and to-day he likes to see these strange creatures that did not outdistance him in the contest of wits.

Paleolithic man was buried with his dog; neolithic man left behind him his horses, sheep, cattle, pigs and goats.

Beginning as hunter, he passed gradually to the stage of property holder and domesticator of the wild.

The Zoo started in the home; the

hunter bringing back the living young of the hunt, appealing to the best in him by their helplessness, their winsome gambols, as well as by their subjugation to his will. Some remained as companions, others as beasts of burden; others were useful for the wonderment and reverence they called forth.

Evidently the poor fish fared worst of all in seeking man's protection in the farm, household or zoo; and for the very reason that makes the fish so intensely interesting to the modern man sufficiently educated to take pleasure in the household aquarium: the fish lives in water; the man must soon come out into the air. Primitive man had no glass globe; the fish perished before they were well seen. To-day we see the fish on our level as one of us, yet living where we have not yet learned to live easily. The bird could be caged; the fish was the unknown mystery never caught in the full measure of its wonderfulness.

However great the gulf between man and beast, the fact remains that they have much in common; what man does, one or another animal has done to some extent. The association of animal with

animal is by no means limited to those of the same kith and kin: see the remarkable present-day Paradise screens taken by the lenses of Shilling in Africa, showing the great herds of most diverse animals all living in one another's company. "*Symbiosis*," the living together of different creatures without harm, one to the other—that is, the fundamental fact in all nature, equally fundamental with the facts of destruction and contest.

Many marvelous chapters of biology tell of the living of animals with quite different animals, of plants with plants, of animals with plants and of plants with animals of all kinds, sizes and grades of being, and in all grades of freedom, and of intimate combination until the companions seem to make but one individual.

Among the ants, whose social communities show some points of resemblance to those of men, there are innumerable cases of "*symbiosis*." There are cases where the ant harbors in its home most diverse little animals, some to be carried about and tended and reared for the milk-like food they let out for the ant, others tolerated as rats and mice



CAPTIVE LION BEING LET OUT OF A PORTABLE WOODEN CAGE
EN ROUTE TO AN ASSYRIAN HUNT. FROM WALL CARVING NOW IN BRITISH MUSEUM; ALSO DRAWING
IN LOISELL'S HISTORY OF MENAGERIES.



MOTHER POLAR BEAR GUARDING FOUR MONTHS' OLD CUB
IN THE ZOOLOGICAL PARK OF MILWAUKEE. THIS CUB WAS BORN LIKE MANY OTHERS IN THIS PARK
WHERE THE MOTHER ADHERES TO HER NATURAL INSTINCTS TO GO INTO RETIREMENT IN THE AUTUMN
AND NOT PERMIT THE YOUNG TO EMERGE FROM COMPLETE ISOLATION TILL MARCH.

about human homes, others overlooked like the kitchen cockroach, others actually enjoyed as man enjoys his hothouse plants, it would seem.

Estimates running ahead of the actual counts of 1,500 kinds put the probable number of species of animals living in the homes of various ants as 3,000.

Even the keeper of a great zoological park, who should also be a farmer and have a house full of insects, may not come into contact with so many diverse creatures as may the ants in their homes.

Granting that the tolerance of other animals is deep set in ant and man and that the hunter saved out the foundations of future house pets, farm animals and menageries, what can be said of recorded steps in the actual history of menageries and zoological gardens?

ZOOS OF ANTIQUITY

The ideal setting for man is the garden, but when man becomes men, neither the flowery garden of the cottage in New Zealand or the public park of the modern city can quite replace the imagined golden age of primitive man with the question of land ownership yet unborn.

And Jahweh planted a garden in Eden, in the East, and placed there the man whom he had formed. And Jahweh made every tree that is pleasant to the sight and good for food to spring from the ground.

And Jahweh formed out of the ground every beast of the field and every fowl of the heaven; and brought them to the man to see what he would call them, and whatever the man called them, that is each living creature, that was to be his name. . . . And the man gave names to all cattle and to the fowl of the heaven and to every beast of the field; but for a man he did not find a help corresponding to himself.

Imagine the bliss of this first naturalist in seeing and hearing enough of all this incomprehensible zoo to give to each its appropriate name. How the first visitors suffered the penalties of not obeying the rules of the zoological garden we know full too well, as Milton describes them.

It was ages afterwards that the first traveling menagerie or transportable zoo was builded by good old Noah, escaping the excessive dampness that has ruined many other zoological collections:

And Jahweh said to Noah: "Come thou and all thy house into the ark. Of every beast that is clean thou shalt take seven pairs, the male with his wife; also of the birds of the sky seven pairs (the male and his wife) to keep seed alive on all the face of the earth."

Thus it came about that all later zoological parks have been stocked from the original Paradise park, while animals that later escaped remained wild to contest the lordship of man.

Save me from the jaws of the lion,
My wretched life from the horn of the unicorns.

The mighty hunters of antiquity soon learned to preserve the beasts of prey for the sport of killing them on occasions.

Daniel in the pit, or den, of lions probably found himself amidst beasts stored up for future hunts.

The Persians kept extensive "Paradises" or parks where were held for future sport in hunting, lions, tigers, wild boars, antelopes and other creatures: a zoological garden with chiefly the king to enjoy it and each animal doomed to sudden death when, for instance, the slaves took out, say a lion in a cage, and released it that the king might overcome it with arms and courage.

Erman, in "Life in Ancient Egypt," describes the men of those days as having a passionate love of the chase, the wealthy at all times keeping menageries in which they reared the young animals taken in the hunt in the desert with lassos or with dogs. They also kept animals brought into Egypt in commerce or as tribute, for in those days the rare wild animal was a precious gift or gold substitute.

They brought in lions, leopards in great cages, hyenas, gazelles, ibex, hares and porcupine from the desert; and



AFRICAN ELEPHANTS AT HOME, AS CONCEIVED BY JOSEPH WOLF
FROM STUDY AT THE LONDON ZOO TO WHICH THE FIRST AFRICAN ELEPHANT, JUMBO, WAS BROUGHT
IN 1865, TO STAY UNTIL 1881, WHEN IT BECAME TOO IRASCIBLE AND WAS SOLD FOR TEN THOUSAND
DOLLARS TO BARNUM FOR EXHIBITION IN THE UNITED STATES.

from the upper Nile, the pard, baboon, giraffe; and from Syria the bear and the elephant.

But not only were the animals hunted to death; there were those who tamed and taught them tricks. Rameses II was followed to battle by a tamed lion that lay by his tent at night. Pet apes were imported and became the favorites of ladies.

Actual descriptions of animals and the mighty kings who hunted them may still be read on Assyrian and Babylonian monuments and supply the best of evidence of the state of the zoological garden in those, its embryo days.

From the papers of Bruno Meissner we gather that on the Prism of Tiglath-pileser I are carved the statements that he was a most successful hunter, boasting of the wild animals he had slain, and that he brought back great numbers of wild animals and not only kept them in captivity but got them to reproduce. He

also went out to sea, in the Mediterranean, and killed a sperm whale "that blows out of the nose hole," whose teeth were used in place of ivory.

These kings were not unmindful of the popular pleasure in exotic animals and made use of this as a means of showing off their supreme power. Tiglathpileser showed the people herds of "trample-thiere" and let them revel in the sight of the gifts sent him from the Pharaoh of Egypt, a great ape, a crocodile, a river man and animals of the great seas.

Not only did this monarch keep the native wild beasts in his gardens, but he was successful in acclimatization experiments, bringing into his country the cedar of Lebanon, as well as elephants and wild oxen.

It was said of him that he hunted in the days of frost and rain and caught in nets both male and female wild goats and deer and kept them in his herds until they reproduced. Apparently these

herds were kept in great parks where they could be hunted. But he also sent merchants to buy dromedaries and these he bred in herds and showed them to the people. He thus laid the foundations of zoological gardens, *three thousand years ago*.

Another mighty hunter, Assurnascirpal, says:

I killed with the bow 30 elephants, 237 mighty wild bulls; I killed from my war chariot in royal battle, 370 mighty lions; I killed with my spear, like caged birds.

This nimrod brought together a fine collection of animals and distributed them amongst the parks of his various palaces, thus forming definite zoological gardens. The fine carving of this king shows three horses galloping over a wounded lion with three spears in its body, while the king in the chariot draws his bow and another man drives the horses. Do we see in this pictured lion one actually saved and kept for the zoological garden of that period, 885-859 B.C.?

This King and Salmanassar III had pictures made on stone obelisks representing the wild apes, elephants, camels with two humps, aurochs. And possibly stuffed skins served to convey some of the lessons of the modern museum; and at all events there seem to be inscriptions complaining of deceit in the representation of the wonders of exotic animal life.

Assurnascirpal records his successes with the same lack of false modesty seen in some great hunters of African beasts, in very modern times. His recorded statements on stone are supposed to say:

On the other bank of the Euphrat river I killed fifty wild oxen and caught 8 living . . . with my strong hand I caught 15 lions in the forests and mountains. I took fifty young lions and put them in cages in my palace and their young greatly increased in numbers. I seized living mindin with my hands. To my city, Kalach, I brought and showed to my people: herds of wild oxen, elephants, lions, lurmu birds, male and female apes, wild asses, gazelles, deer, parads, and sinkurri; all sorts of animals of the plains and of the mountains.

Surely does history repeat itself, but



BEARS IN A MOATED ENCLOSURE WITH NO BARS TO KEEP VISITORS OUT AS SEEN IN "THE WORLD'S FINEST ZOOLOGICAL PARK" AT ST. LOUIS. MANY OTHER ANIMALS ARE ALSO SHOWN IN MOATED ENCLOSURES. THE VISITORS SAFELY, AT CLOSE RANGE, SEE THE ANIMALS MUCH AS IF IN THEIR NATIVE HABITATS.



FEEDING A CAPTIVE PORPOISE UNDER WATER IN HUGE TANK.
OF ALL THE MAMMALS, THE WHALES OFFER SOME OF THE GREATEST OBSTACLES TO CAPTURE AND
CONFINEMENT IN ZOOLOGICAL PARKS, BUT AT LENGTH THESE SMALLER MEMBERS OF THE WHALE
TRIBE HAVE BEEN TAKEN AND KEPT WITH SUCCESS; AT LEAST ONE WAS BORN IN CAPTIVITY.

present democratic spirit makes the Roosevelt Wing of the American Museum of Natural History a rather different factor in education than were the great collections of this royal hunter of Assur.

This policy of combining the king's pleasure with that of the people in the matter of zoological gardens was followed by his successor, Salmanassar, who imported rare plants and animals. On the "black obelisk" are depicted the figures of animals sent him as tribute: camels with two humps, oxen (perhaps the aurochs), an antelope, animals with horn between nose and forehead, and great apes walking or being carried.

A still later monarch boasted that at the command of God there grew in his gardens various exotic trees and fruits, better than in their native lands, while the wild swine and other animals gave birth freely and the bird of heaven (the swan?) built its nest, although its home was in far distant lands.

Thus in the Assyrian civilization, zoological gardens of some sort were to some slight extent engaged in by the people, but far less so than at present when even the most dictatorial park board would hesitate to import animals without some reference to the vox populi howling in the press.

Flower, the director of the Zoological Park near Cairo, states that the ancient Egyptians had zoological parks.

But other civilizations found the need of zoological gardens as culture advanced. But here we lack stone monuments and inscriptions for the first beginnings. Yet it is stated in encyclopedias that in the old Chinese civilization, in the China (which began and invented everything and then forgot all about it in the centuries that passed), in China, which to-day is so denuded of its former wild life and so pleased with its gold fish, china images and grotesque

dogs that there is little interest in the zoological park; in this China in the year 1150 B.C. the "Park of Intelligence" was maintained by the great founder of the Tschou dynasty at Lin Yo. This great zoological park, where the Emperor was pleased to walk to view the animals enjoying themselves as in their native wilds, contained mammals, birds, turtles and fish.

It was then a comprehensive collection appealing to those who loved bird, beast and fish. If, as is stated, this garden endured on into the fourth century, B.C., it outranks in age of existence all the zoological gardens that have ever started, although of course some now existent *may* last as long.

How very ancient the civilizations of America may prove to be remains yet to be determined; but it is interesting to learn that on this continent also zoological gardens came to be recognized as part of the higher culture. Montezuma, the last of the Aztec leaders in Mexico, had a menagerie in one of his pleasure houses, where there were a long series of aquaria of water containers, bird houses and cages, wild animals, birds from all parts of the realm, from giant condors to pigmy humming birds. There were also snakes and lizards. Both salt water and fresh running water was provided in this zoo.

So great was the collection that 300 attendants were working to care for the animals and to collect feathers for the artistic mosaic work carried on in this connection.

This was not the only zoological collection of that country. Both the contemporaries and the forefathers of Montezuma maintained similar menageries.

HISTORY OF EUROPEAN MENAGERIES

European civilization, with its long series of interactions of princes, church and people, has also developed the zoo-



EIGHTEENTH CENTURY VIEW OF A PRIVATE MENAGERIE

BELONGING TO JAN A. BLAAUW OF AMSTERDAM, IN WHICH THE VISITORS ENJOY INTIMATE ASSEMBLY WITH THE BIRDS AND MAMMALS WHILE PARTAKING OF REFRESHMENTS, THUS FORECASTING THE ASSOCIATION OF ZOO AND RESTAURANT LATER SO PREVALENT IN MANY COMMUNITIES.

logical garden, from the toy of the king or churchman to the possession of the city and its people.

From the publications of the old zoological society of Frankfort, Wilhelm Stricker has collected the following statements that show the slow advance in the status of the zoological garden in various states of Europe.

If there be any truth in the idea that Aristotle had for study collections of animals sent him by Alexander the Great, these were surely not connected with zoological gardens, and the same may be said of many collections of wild animals brought together by the Romans for feasts and spectacles of the arena.

But as early as the tenth century we are told the zoological collections of the Monastery of St. Gallen, site of an Irish hermit's dwelling, contained both native animals and those from a distance, such

as bears, badgers, marmot, wild goats, deer, silver pheasants. Some of these were donated by visitors.

Other religious houses also found the zoological park a welcome addition to their means for contemplation and intellectual activity.

In 1408 the grand master of the Teutonic order at Marienburg received a lion as a present and this was added to his zoological garden—his menagerie—with deer, bears, apes of different kinds, as well as "sea cows" and "sea oxen" (?), and large wild cattle, four of them the present of the Prince of Lithuania.

Some of these animals, the apes, were taken into the house at times, while outdoors there were also large enclosures for rabbits. Other grand masters kept rabbits, and the gift of these animals was a common courtesy.

In the sixteenth century the menagerie

of the grand master, later the Duke of Prussia, served as a source for animals that were sent to other zoological collections. Thus in 1518, fine aurochs (*Bos taurus*) were sent to Brandenburg and to the King of Denmark. Animals again served, as in Assyria, for gifts and tribute.

The Emperor, Frederick II, received from friendly rulers of the East both lions and tigers, leopards and camels, as well as giraffes. The cities also began to please the people with exhibitions of wild animals.

In 1399 Frankfort had collected some deer, but this was a very modest beginning, and in 1400 there were but two animals, one the present of the Jew, Gottschalk von Kreutznach; but in the eight years they had increased so that the yearly feast of the city council did not keep down the deer sufficiently, and in 1444 the council gave some of the deer away to certain zoological gardens, as at Munzenberg. This experiment in city park breeding of deer was, however, abandoned in 1556 and so did not lead up to the present zoological park of the city of Frankfort.

The town of Berne, Switzerland, had six bears in 1551. Down in the Netherlands the appreciation of the animal collection was early shown. In the fourteenth century the woods of the Count, The Hague, contained buildings for dogs, falcons, fowl and also lions, bears, dromedaries. Other princes had their collections and maintained special masters of fowls, parrots and birds. At Rosendaal, in the year 1398-1399, the lions in this garden consumed a total of 260 sheep. Previously, in 1384, as many as 200 wolves had been used for the same purpose inside of five months. But all expenses were not so great, for we read that the man who took care of the lions received but two grotes a day in 1664!

Amsterdam, the city, had its own collections and received lions as presents

from merchants—two from Spain in 1488 and two from Portugal in 1483. A few years later Amsterdam gave five or six of its lions to the city of Luebeck. Ghent also had its collection of lions.

While these royal beasts were being handed about between cities and princes, other gold substitutes were found in the rare and bizarre parrots, a sort of animated greenback, the council of Nuremberg paying out fifty pounds in 1458 to send a parrot to the Bishop of Mainz, and sixty-five pounds in 1460 to send another parrot to the Queen of Bohemia.

At what date the elephant appeared in Europe as a show animal worthy of being a royal gift is difficult to find out, but in 1551 Maximilian II brought into Germany from Spain a male elephant and used it in the triumphal entry into Vienna, in 1552, as King of Bohemia. But before that several inns had been called "The Elephant"—one in Strassburg, 1343; one in Frankfort, 1404; and it was said that an elephant had been exhibited in Frankfort in 1443 or 1480.

The royal menageries of Austria laid the foundations for very important developments in zoological gardens. At Ebersdorf, near Vienna, Maximilian, the eldest son of the Emperor Ferdinand, had a menagerie which was much enriched by the addition of foreign animals brought in by the enthusiasm of Rudolf II (1552-1612) who, however, let the collection die out while he started a second menagerie about 1570 at Neugebau. This second collection was maintained and enlarged by Leopold I and in this period of the history of the garden occurred the tragic episode described in Chamisso's poem, "The Lion's Bride."

Although the Hungarian rebels destroyed this collection in 1704, it was started again in 1738 by Karl VI, who added to it the lions he got from the collection of Prince Eugene, at his death in 1736.

But even this second attempt was



WATERFOWL LAWN AT THE LONDON ZOO IN 1830

WHEN VISITORS AND THE BIRDS ON DISPLAY APPEAR WELL SATISFIED WITH THEIR COZY ASSOCIATIONS.

abandoned in 1781 and did not continue on to the present day, even though it had been thus permanent for two centuries.

Ebersdorf and Neugebau may be cited as the first and second names in the long list of European menageries or zoological gardens.

A third name, also in Austria, is that of Belvedere, where the above Prince Eugene started in 1716 a menagerie which, although not long enduring, had in it a fine old bird of prey, *Gyps fulvus*, that lingered on in captivity to the very old age of 117 years, and died just before 1824.

Important amongst these old royal menageries was the one at Dresden, which was started in 1554 as the royal Polish collection and increased and well kept up so that the King, in 1731, sent out to Africa a scientific expedition to obtain more animals for this large zoo.

During all this time zoological gardens had sprung up in other parts of Europe; between 1673 and 1730 there

were menageries at Cassell and at Karlsruhe, and one at Potsdam in 1702.

In this eighteenth century also there began those collections of wild animals in England that for a time satisfied the popular demand but later blossomed out as the great collections of the Zoological Society of London.

Already, in 1761, the Tower of London contained a menagerie of lions, tigers, leopards, hyenas, apes and birds, including an ancient eagle that lived ninety years in captivity; this was not the fate of many another biped confined in the Tower.

The early beginnings made in Austria were not by any means lost, but were gathered up in a new royal menagerie lasting down to our times, so that in 1907 the Emperor of Austria paid out some 258,400 crowns to support his private menagerie of 363 mammals of 160 species, his 1,351 birds of 345 species, and his 171 reptiles of 47 species. The origin of this very romantic and elegantly housed collection which became

associated with some great events of history was as follows:

At Schönbrunn, in 1752, this famous royal zoological collection began when the Emperor Francis I and the Empress Maria Theresa brought in the services of the landscape gardener, Adrian von Steckoven of Holland, to plan out a garden along the lines of that of the animal lover, Prince Eugene of Savoy. A remarkable creation of solid walls thirty feet high and buildings thus arose in the forest. To this were brought all the wild animals housed in the Neugebau collection and in the Belvedere collection, and to these were added many new purchases from Holland and from England. For this great zoological garden the Emperor also sent Nicolas Jacquin in 1754-59 to the West Indies, and to South America to collect plants and animals for his garden.

In 1759-60 the royal pair built in the

midst of the garden an octagonal house, where in the summer time they took their breakfast and looked at the live animals from the windows and doors, or at the walls adorned with paintings.

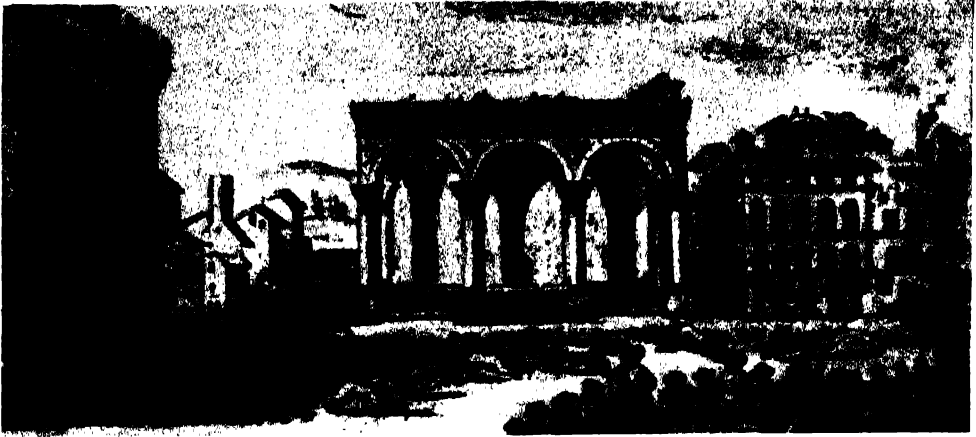
To maintain and strengthen this imperial menagerie, the Emperor Joseph II took away from the Neugebau collection all the remaining animals and added them to Schönbrunn in 1781, and moreover sent out two scientific expeditions to North America and to the East Indies in 1783-85, followed up in 1787-88 by expeditions to South Africa, Isle of France and Bourbon to add to his great private zoo.

Francis II rebuilt the menagerie of Schönbrunn, buying up traveling menageries in 1799, 1824, 1826, and added also the collections brought back by the Austrian expedition to Brazil.

In 1828 the giraffe sent to Vienna as a present from Mohamet Ali appealed



PLAN OF THE GROUNDS OF THE ZOOLOGICAL SOCIETY OF LONDON .
IN ITS EARLY DAYS, 1829, WHEN AS PROPERTY OF THE SOCIETY IT WAS OPEN ONLY TO MEMBERS
AND SUCH OF THE PUBLIC AS OBTAINED CONSENT OF MEMBERS. AT THAT PERIOD IT WAS SAID "THE
VULGAR ARE TOO FOND OF IRRITATING THE FIERCE ANIMALS AND OF TEASING AND OF HURTING THOSE
THAT ARE GENTLE."



LIONS KEPT IN ONLY PARTIAL CAPTIVITY IN COURTYARD OF OLD PALACE FLORENCE, FIFTEENTH OR SIXTEENTH CENTURY. THUS THE BARLESS ENCLOSURE FOR WILD CARNIVORA HAD ORIGIN FAR BACK OF THE INVENTIONS OF CARL HAGENBECK AND MODERN USAGE. IT IS EVIDENT THAT THE VISITORS COULD ENJOY FULL VIEW OF THE LIONS AND WITH SAFETY, ESPECIALLY IF ON TOP OF THE TALL BUILDING, WHILE THE LIONS SEEM TO REJOICE IN ABSENCE OF BARS BETWEEN THEM AND THE SKY.

greatly to the imagination of the Viennese and became the subject of much literature and started a fad for giraffe-shaped pianos, giraffe hair combs, giraffe hair dress, etc.; but the giraffe died after ten months and thirteen days of deification.

At one time this famous Schönbrunn collection was subdivided in the making of two specialized Vienna menageries, but it was again restored and enlarged by purchase of traveling menageries by the Emperor Ferdinand I in 1837, and the next year was made more useful to the public by the addition of signs bearing the scientific name and the country of origin of each animal.

Thus it continued, becoming more and more open to the public, although a private possession of the Emperor, with sometimes the need of restricted use when abuses followed too great freedom of access.

Thus the playthings of kings may sometimes be shared by the people.

So it fared in France likewise, where the great museum and zoological park, the "Jardin des Plantes," coddled in

infancy by the King, becomes, full grown, the school of the republic.

It seems that Louis XIII entrusted his two physicians to purchase twenty-four acres of land and buildings for the *culture of medicinal herbs*, in May, 1636.

Under Louis XV, in 1732-30, this royal garden was rejuvenated by its director, Dufay, who gave to it his own collections and brought it about that the great zoologist, Buffon, was appointed as his successor in 1732.

This was the zenith of success of the royal garden: Buffon, Daubenton, Bernard de Jussieu and later Lurent Jussieu, Rouelle, Foureroy, Lavoisier, Winslow, Portal and others made of this institution, up to the time of the Revolution, the leading scientific institution of the world.

But, however successful, this combination of king and scientists was temporary. Buffon died on the eve of the Revolution, April 16, 1788.

In 1790 the royal garden was taken away from the king, but it was decided to continue it enlarged as the Museum of Natural History, to which in 1793 a

menagerie was added, as suggested by Buffon, by the foundation of a library and museum of natural history, opened on September 7, 1794, with an annual appropriation of some \$30,000. At this same time the royal menagerie, founded by Louis XIV and made larger by his successors, was taken away from Versailles and added to the garden by the efforts of Bernadine St. Pierre after much discussion of the best way to house the collection at Versailles after the destruction of royal power, September 21, 1792. Although the mob had destroyed much there were still the remarkable animals, a quagga, a hartebeest, a crested pigeon from Banga, an Indian rhinoceros and a lion from Senegal living in great friendship with a dog.

Thus did the old king's garden and menagerie of the palace unite with the museum and library of the commonwealth to make the unique zoological park ever since famous as the "Jardin des Plantes," for the Frenchman can

not give up the old name, loving the form if not the substance of royalty.

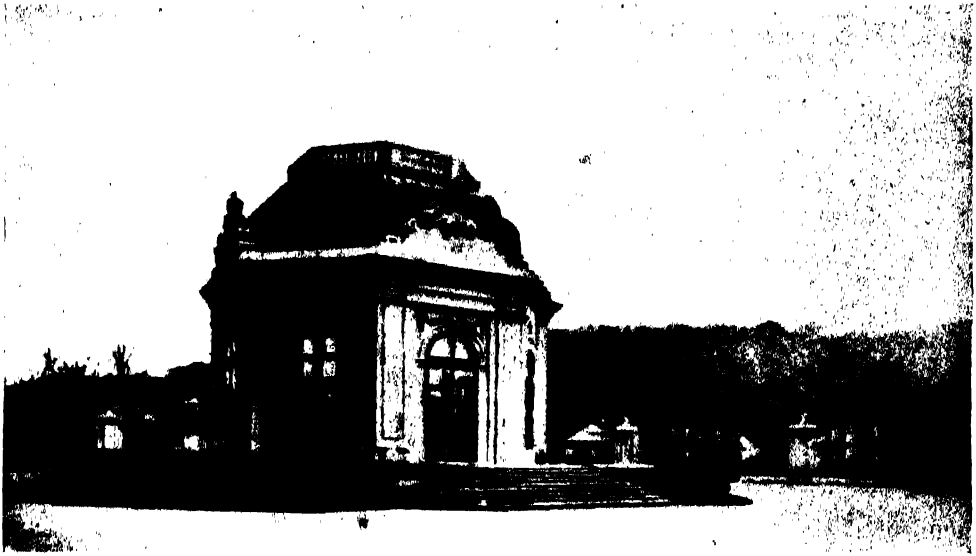
The zoological garden in the old king's park was very popular and was soon rapidly enlarged by presents, by a shipload from Trinidad in 1796, by collections from Guiana and by an expedition to Africa in 1797 under Cassell.

Under the Consulate, the Jardin des Plantes flourished greatly and became a second time the center of scientific activity, publishing from its Museum of Natural History 20 quarto volumes of *Annales* in 1802-13; 20 quartos of *Memoires* in 1850-; 14 quartos of the *Nouvelles Annales* in 1832-35; and ten quartos of the *Archives*, 1840-58.

As under the old régime, the garden had greatly aided Buffon in his great philosophical Natural History volumes, so that the new Jardin des Plantes was the chief support for the great work of Cuvier on the Animal Kingdom, which so deeply impressed the advance of science.



RADIAL ARRANGEMENT OF MENAGERIE OF LOUIS THE FOURTEENTH
AT VERSAILLES, 1638-1715.



THE FAMOUS ROCOCO OCTAGONAL PAVILION WITH COPPER ROOF
BUILT IN SCHÖNBRUNN IN 1759, AS IT APPEARED TO LOISELL IN THE TWENTIETH CENTURY.

But gradually the garden got into financial straits so that Cuvier, as professor of comparative anatomy in the Jardin des Plantes, wrote, in 1800, that the members of the staff were twelve months in arrears in their salaries.

Here also labored Lamarck, the radical and original spirit in the zoology of the garden.

The lectures of Cuvier, given to large audiences with free-hand sketches and illustrative material from the collections of the garden, greatly added to the reputation of the Jardin des Plantes and means were found for sumptuous publications in natural history. For the first time many animals were well represented in pictures from life in colored copper plate published in the splendid folio, "*La Ménagerie du musée national d'histoire naturelle*," by Cuvier and Lacépède, in 1801; and this was republished and brought up to date in 1817 as two quarto volumes with 58 copper plates. The Emperor Napoleon added to the garden, tigers, lynx, mandrill, leopard, hyenas, panthers and birds and

plants which he bought in England, and in his wanderings he remembered the museum with gifts of fossils and rocks from Corsica. One expedition brought in 100,000 animals, small and large, with a zebra and a monkey for the Empress Josephine. Other collectors returned from Lisbon, America, Italy and Germany.

The condition of the menagerie in 1823 may be read in a book on Paris and its inhabitants by Moeller, Gotha, 1823, pp. 210-216.

When Geoffrey Saint-Hilaire was professor of zoology in the garden in 1841, there were then museums of zoology, of comparative anatomy, of botany, of geology and of minerals, with a large library of 28,000 volumes on travels, natural history, botany, physics, chemistry, mineralogy, comparative and human anatomy and zoology.

Its condition in 1849 is related in the book of "Esquires and Weil," Stuttgart, and there is another account in 1861 in the "Journey of Dr. Weinland."

The menagerie in the garden received

much from Mohamet Ali, Pasha of Egypt, so that it came to have not only Arabian horses and antelopes, but an African elephant. Most astounding of all to the people was the giraffe sent by the ruler of Senaa, as the first to set foot on French soil. Taken young and reared on camel's milk, the journey was broken by three months in Cairo, and then continued to Marseilles by boat with three cows to supply the milk. Arriving on November 14, 1825, when twenty-nine months old, the young giraffe remained over winter to start on May 20, 1827, on foot to Lyons, where it arrived safely on June 5, and thence by short laps to Paris. Another giraffe sent then by the Pasha to England died at Malta. In France the giraffe made a stir, as had the first giraffe in Austria. A number of scientific papers show the excitement of this event.

Other giraffes fared less well. One died in Toulouse in 1844; another on

the way to London died in 1829 from disease of the joints, perhaps arising from riding on camel's back with knees doubled up.

The Jardin des Plantes of the present century has recovered from the evil days when, in 1870, a hundred shells fell within it, ruining most of the glass houses, and when the animals were decimated that many might be used as food. Two African elephants ("Castor and Pollux"), two camels, four elands, all the stags, nilgais, etc., went to the butcher. Lion, bear and hippopotamus meat selling at five dollars a pound, and hard to get even at that price!

Here then we still have some of the old king's garden with fine old cedars of Lebanon, old museum collections of the times of Lamarck, Cuvier or Buffon, as well as a very popular free menagerie dispersed amidst fine trees and shade.

(To be continued)

A POSITIVE PHILOSOPHY

THE university can, however, contribute directly to national defense in a fourth field—the field of ideas. I do not mean that the faculty should embark upon a campaign of propaganda nor that in an effort to combat the political philosophy of Hitler we should incorporate his methods in our educational institutions. I am not suggesting a witch-hunt directed against those whose ideas do not coincide with ours. The principle of freedom to express ideas is sound now, in a period of emergency, as in normal times. But that freedom does not imply the desirability of a neutral attitude between what we feel is right and what is wrong. It does not divest the leaders in a university community from the responsibility for guiding the students and public opinion in the direction of what they believe to be right. During the past two decades our universities have suffered from a negative complex; our faculties have analyzed issues and balanced factors; they have exposed the follies and the vices of historical figures and movements; they have not emerged with a positive philosophy to which students and public might attach themselves. There is justice in the

complaint of the undergraduate that his academic experience had not provided him with a faith.

Appreciation of values becomes most intense when they are in danger. It is likely that the present emergency will revive faith in our American way of life and enthusiasm for its preservation and development. The universities must take the lead in this resurgence of conviction, which alone can give to the nation a unifying force. They have been the first to profit by the freedom and security proceeding from our American system; they are the most keenly alive to the spiritual values that disappear in a totalitarian system; to them is entrusted the guidance of the youth of the land whose lot it is to defend and carry on the American tradition. This is a responsibility that has fallen upon our shoulders and which we can not evade. If it is properly fulfilled our young men will graduate with a flaming faith in the American ideal. No other contribution to national defense which we can make will be of equal importance.—*Report of the President, Yale University.*

LIVING GUIDE-POSTS OF THE PAST

By Dr. **RAYMOND E. JANSSEN**

GEOLOGIST, EVANSTON, ILLINOIS

THROUGHOUT the Mississippi Valley and Great Lakes regions, may be seen numerous curiously bent trees. The casual observer views them merely as deformed freaks; but careful observation and comparison of the nature of the deformities indicate that these trees did not acquire their strange shapes simply by accident.

These trees exhibit an acute or right-angled bend in their main trunks, usually from two to five feet above their bases. Rising vertically from the bent trunks are one or more lateral stems, or secondary trunks, bearing the branching structure and leaves. Ages of the trees

range from somewhat more than a hundred to two, and three, hundred years.

Although these trees have been growing in their respective situations for long periods of time, no reference concerning them may be found in previous scientific literature. Scattered historical references, however, indicate that trees were sometimes bent by the Indians to mark trails through the forests. Consequently, a study was carried on over a period of several seasons for the purpose of determining whether such trees still standing might have been deformed intentionally by Indians who formerly inhabited mid-western America.

This study indicated that the use of trees for trail markers was a custom apparently inaugurated by the forest inhabiting natives of North America long before the advent of the white man. The custom arose, no doubt, because trees were the most accessible and most easily adaptable materials at hand. Because of their flexibility, living trees could be contorted into unnatural shapes, and being rooted they could not easily be removed. Also, by using a few trees out of many, the Indians could make these markers as conspicuous or as inconspicuous as desired; hence trees made ideal guide-posts.

In order to establish certain trees as markers, the Indians inhabiting wooded regions developed the custom of bending saplings and fastening them in position in such a way that they became permanently deformed. A long line of similarly bent trees could thus be followed by proceeding from one bent tree to the next. Once a trail was established, the Indians could follow these markers through swamplands or across difficult

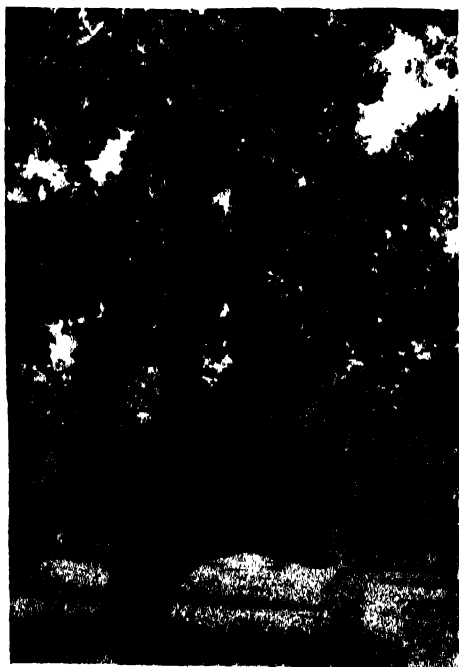


FIG. 1. STURDY OLD BURR OAK
ALTHOUGH ABNORMALLY CONTORTED, IT EXHIBITS
ALL THE STATELINESS OF ITS SPECIES. IT IS
SITUATED NEAR THE CHICAGO RIVER, NORTH OF
GLENVIEW, ILLINOIS.

terrain without unnecessary delay, and could maintain their direction while traveling long distances through densely wooded and unfamiliar territory.

Observation had taught these primitive people that trees do not heighten *en masse* nor turn on an axis. They noticed, too, that trees when once deformed maintained their deformities throughout subsequent periods of growth. Thus it became possible to deform trees deliberately in order to distinguish them from the ordinary trees of the forests. In bending the young trees, care was taken so as not to break them. As a result they did not die, but continued to grow in the deformed positions. Whether by accident or intention, by deforming living trees, the Indians left behind them a series of permanently marked trails. Although a hundred years and more have elapsed since the Indians were forced westward from the Mississippi Valley by the advancing white man, their old trail markers may still be growing just as they were when first established so long ago.

It has been found that various methods of securing the saplings in position were used, depending on the materials at hand and the custom or ingenuity of the individual performing the task. Sometimes the trees, after being bent, were weighted down with a rock if one could be found nearby. Occasionally they were staked; sometimes a pile of dirt was used. But more frequently the trees were tied in position with a strip of rawhide, bark or tough vine (see Fig. 3).¹ In each case the trees were fastened so that the direction of bend was parallel to the direction of the trail to be followed. Each tree was thus a pointer directed toward, or away from, the next marker in the trail.

As might be expected, the deformation

¹ The latter method is reported to be in use at the present time among the jungle natives of the Philippine Islands. Personal communication from Dr. Fay-Cooper Cole, University of Chicago.

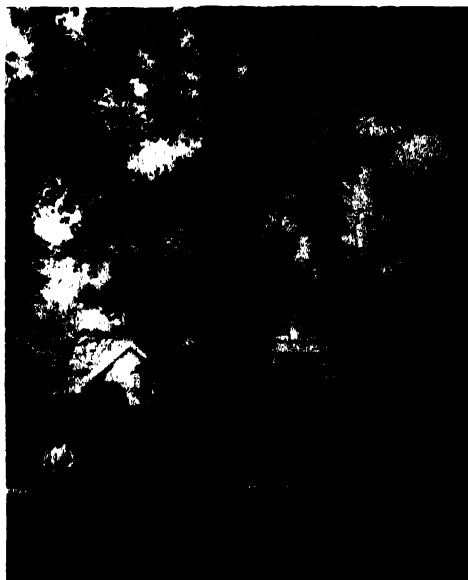


FIG. 2. AN INDIAN MARKER IN WILMETTE, ILLINOIS. IN REGIONS WHERE INDIAN MARKERS STILL EXIST, THEY MAY OFTEN BE SEEN ALONG THE STREETS OF TOWNS.

of saplings had a serious effect upon their subsequent development. The trunk and branches which had previously held the leaves up to the sunlight were suddenly distorted earthward, and hence could no longer function normally. Compensation for this unnatural position, and resumption of normal growth, occurred only after new vertical branches—secondary stems—began to appear along the bent primary trunk. During this readjustment period, growth was much retarded, normal development being restored only after the new stems and branches became well established. The extremities of the original bent-over trunks usually atrophied and decayed away, leaving the trees with a sort of “arm and elbow” appearance (Fig. 4). But occasionally the original trunk tip took root at its point of contact with the ground. When this happened, the tree functioned thereafter with two sets of roots (Fig. 6). Observations of growth rings on trail trees showed that they

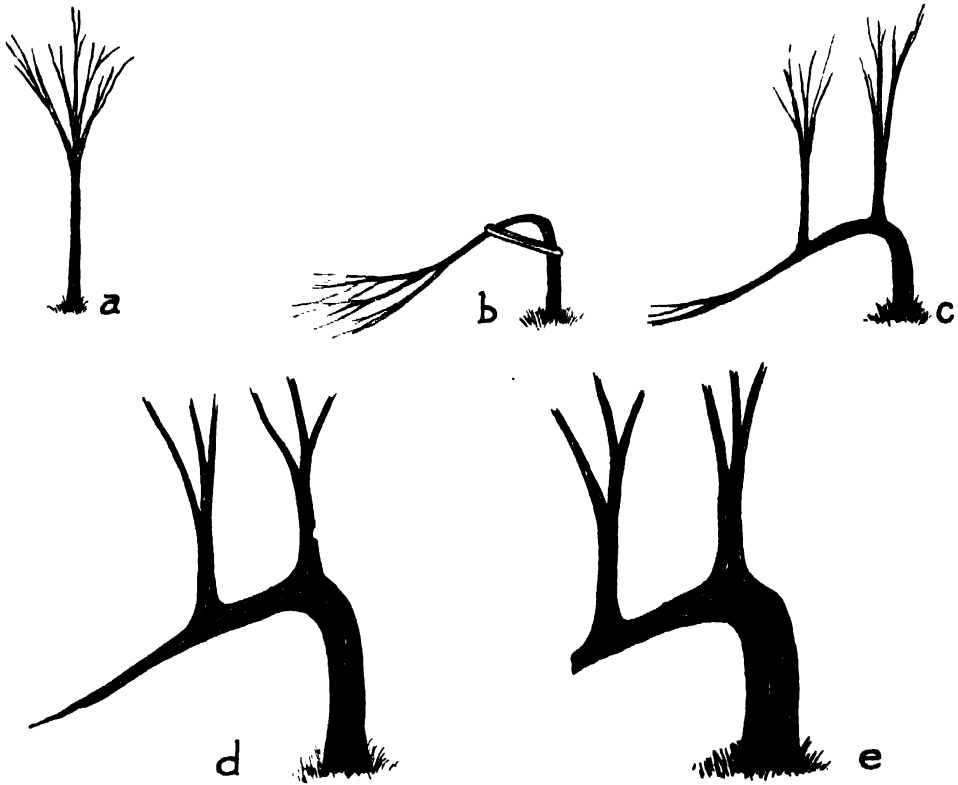


FIG. 3. COMMON METHOD OF ESTABLISHING TRAIL TREE MARKERS

a. SAPLING, YOUNG ENOUGH TO WITHSTAND ACUTE BENDING NEAR BASE. b. TREE BENT AND HELD IN POSITION BY HITCHING WITH RAWHIDE. c. LATER, SECONDARY STEMS APPEAR ALONG THE BENT TRUNK, REPLACING THE ORIGINAL BRANCHING STRUCTURE. d. SEVERAL SEASONS LATER, THE NEW BRANCHING STRUCTURE HAS MADE CONSIDERABLE PROGRESS, WHILE THE ORIGINAL, PROSTRATED BRANCHES HAVE DISINTEGRATED. e. YEARS LATER, THAT PORTION OF THE TREE BEYOND THE POINTS OF EMERGENCE OF THE SECONDARY STEMS HAS ENTIRELY ATROPHIED AND DECAYED AWAY.

were severely stunted by such treatment. Their sizes, therefore, are not as great as normal trees of the same ages.

The question naturally arose as to whether or not the Indians used any kind of selection in their use of trees for trail markers. The wide variation in tree types constituting trail markers indicates that any apparent selection was purely coincidental. The Indians necessarily had to limit their selections of markers to whatever types of trees happened to be growing along the proposed route. Some species of trees are more easily bent at sharp angles without breaking than are others. Deciduous trees, such as oaks, elms, hickories and

maples, are best suited for this purpose. Hence, the custom of using tree markers was limited largely to regions wherein the dominant forest growth at that time consisted of such broad-leaved trees. Bent tree markers seem never to have been used in localities of high altitude or latitude where the less supple coniferous trees are dominant. On the other hand, tree markers were used quite widely in many parts of the Mississippi Valley, the lower Great Lakes region and eastward, where deciduous timber constituted the dominant forest growth.

Even a deciduous tree, however, must be quite young in order to permit its main stem to be bent at a sharp angle

near the ground without being broken. Occasionally no tree young enough for this purpose happened to be growing in a spot where a trail marker was desired. In such a case the Indians resorted to the bending of the lowermost branch of an older tree (Fig. 8). The effect upon that particular branch was similar to that upon the main stem of a young sapling—the branch put forth new secondary branches which extended upward at an odd angle in relation to the main branch.

It is easy to see that an Indian trail, extending across country for many miles, might contain markers consisting of various species of trees, as well as of trees bent in either manner. The species of tree was of no concern whatever as long as it was suitable for bending. The manner of bending, as has been seen, was dependent upon the age of the tree, the materials at hand, and the custom or

ingenuity of the individual performing the work. Of extreme importance, however, was the direction of the bend. The trees were always bent so that they pointed parallel to the direction of the trail to be followed.

Although remaining tree markers are relatively few and far between, it appears that they were originally spaced at varying intervals, depending upon the density of the forest and other conditions encountered along the proposed route. Sometimes they were only a few hundred feet apart. At other times they may have been separated by distances as great as a half mile. North of Chicago there is a marked trail extending from the shore of Lake Michigan to the site of a former Indian village in the Skokie Valley five miles away. This trail crosses the central part of the town of Highland Park, Illinois. Thirty years ago there were eleven markers along this



FIG. 4. "ARM AND ELBOW" ASPECT SUBSEQUENT GROWTH, WITH THE ISSUANCE OF A SINGLE SECONDARY STEM, CAUSES THE MARKERS TO ASSUME THIS SORT OF APPEARANCE. THIS ONE STANDS NEAR FOX LAKE, ILLINOIS.

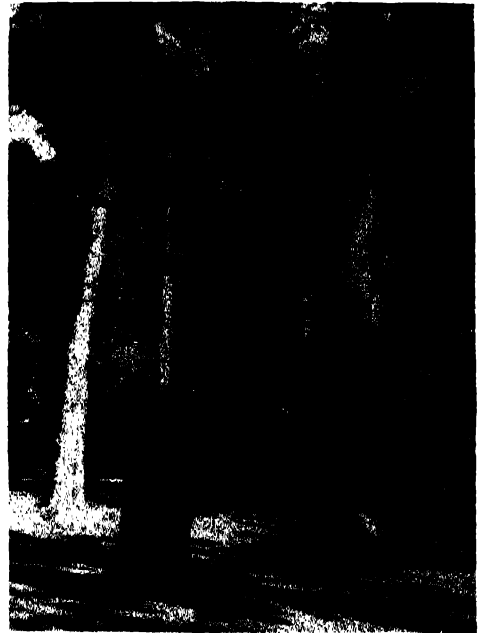


FIG. 5. KNOB CLEARLY SEEN THE SMALL KNOB, MARKING THE POINT OF ATROPHY OF THE ORIGINAL TRUNK TIP IS CLEARLY SEEN IN THIS MARKER. TREE SURGERY HAS AIDED IN PROLONGING THE TREE'S LIFE.



FIG. 6. THIS MARKER NOW FUNCTIONS WITH TWO SETS OF ROOTS THE TREE BECAME ROOTED AT ITS POINT OF SECONDARY CONTACT WITH THE GROUND. IT IS ONE OF A LINE OF SEVERAL TREES MARKING A FORMER TRAIL THROUGH HIGHLAND PARK, ILLINOIS.



FIG. 7. A SORT OF MONUMENT IN A PUBLIC PARK WHEN PROPERTY IMPROVEMENT NECESSITATED THE REMOVAL OF THIS TRAIL MARKER, THE LOCAL D. A. R. CHAPTER RELOCATED IT AS IT APPEARS HERE AT EVANSTON, ILLINOIS.

route—to-day only seven remain. In this trail the closest markers are less than two hundred feet apart, and the farthest more than a half mile. Undoubtedly, they were originally spaced at relatively close intervals. Construction of buildings and civic development have since taken their toll from the original line of markers.

In the course of the study, attempts were made to locate additional unknown markers by plotting known ones on the maps and extending their bearings as indicated by compass readings. In several cases, additional markers were thus located. In other instances the sites of former markers were confirmed through interviews with old settlers and property owners.

Local interest in these trail markers has recently inspired many property owners with the desire to preserve as long as possible these living monuments



FIG. 9. LOCATED ON GOLF COURSE HAVING ONCE STOOD IN THE MIDST OF A THICK WOODS, THIS MARKER IS ONE OF A FEW TREES ALLOWED TO REMAIN WHEN THE LAND WAS CLEARED FOR AN EXCLUSIVE SUBURBAN GOLF COURSE.



FIG. 8. LOWER BRANCH BENT WHEN NO CONVENIENT SAPLING HAPPENED TO BE GROWING AT A LOCATION WHERE A TRAIL MARKER WAS REQUIRED, THE INDIANS RESORTED TO THE BENDING OF A LOWER BRANCH ON A LARGER TREE.

on their lands. Consequently, timely tree surgery has prolonged the lives of many of these old trees. In a few instances, clubs and civic organizations have placed bronze markers on, or near, such trees (Fig. 7).

Among the many crooked trees encountered, only a few are Indian trail markers. The casual observer often experiences difficulty in distinguishing between accidentally deformed trees and those which were purposely bent by the Indians. Deformities may occur in many ways. A large tree may fall upon a sapling, pinning it down for a sufficient length of time to establish a permanent bend. Lightning may split a trunk, causing one portion to fall or lean in such a way as to resemble an Indian marker. Wind, sleet, snow or depredations by animals may cause accidental deformities in trees. However, such injuries leave scars which are apparent to

the careful observer, and these may serve in distinguishing such trees from Indian trail markers.

Observations have shown that the fall of a large tree upon a young one will cause the latter to bend in a wide arch beginning from the tree base. Indian trail markers are never bent from the base. The bend is usually from one to five feet above the ground and forms a rather sharp angle. Also, unless trail trees have been subsequently injured, they do not bear scars other than the knob left by the decay of the original trunk tip. Such knobs might be called remnant-scars as compared to injury-scars. In any event, a line of similarly bent trees, spaced at intervals, and all directed parallel toward or away from each other, would preclude the possibility of accidental deformity.

There is a popular notion that the Indians possessed an infallible sense of direction, and consequently required no

trail markers. Even though it be granted that the savage possessed a keener sense of direction than his white brother—whether it were a natural instinct or the result of practice in the ability to read and interpret natural phenomena—it does not necessarily follow that a mere knowledge of the right direction is the only information needed to travel readily from place to place. There are numerous reasons for marking a trail, even though the general direction to be traveled is known. A direct route from one locality to another might be obstructed by natural barriers such as unusual elevations or depressions, non-fordable bodies of water, treacherous swamps or dense thickets of thorny underbrush. To facilitate travel, a marked detour might be advisable. Then, too, a hunting party in search of game might wish its route to be followed by the squaws who could collect the game and bring it back to camp. Scouts



FIG. 10. SUBSEQUENT GROWTH AFTER BENDING
THAT PORTION OF THE TREE IN THE NEAREST DIRECT LINE WITH THE ROOTS HAS BEEN FAVORED.
SUCH GROWTH IS COMMON TO MARKERS WHICH HAVE PRODUCED MORE THAN ONE SECONDARY STEM.



FIG. 11. MARKER NEAR WISCONSIN RIVER AT WISCONSIN DELLS
THIS IS ONE OF TWO SUCH TREES STILL STANDING IN THAT LOCALITY.

sent out in advance of a raiding party might wish to mark their trail so that the warriors might follow them into unfamiliar territory. Various other reasons may suggest themselves. However, long-established and important routes of travel probably were not marked, inasmuch as the paths themselves, worn well into the ground, were readily followed. The trail markers were undoubtedly placed along routes which were temporary or less frequently used than the main thoroughfares of Indian travel, or along new routes which later became heavily traveled.

Only for the past hundred years has the Mississippi Valley, in its entirety, been the undisputed home of the white

man. During the preceding centuries it was, in turn, the domain of some of the strongest tribes of the North American continent. Much of the Indian history of those early days must, of necessity, remain forever unknown; but a portion of that history is simply told by the old trail markers which may still be found growing in numerous localities.

Because of the longevity of trees, many of these old trail markers, now gnarled with age, still stand as living reminders of the time when mid-western America was a favorite hunting ground of the savage red man. A few more years, perhaps, and the last of them shall be gone forever—as are the Indians who bent them.

AEROEMBOLISM: A MEDICAL PROBLEM IN AVIATION AT HIGH ALTITUDE

By Dr. W. RANDOLPH LOVELACE, Dr. WALTER M. BOOTHBY and
Dr. OTIS O. BENSON, Jr.

THE MAYO CLINIC, ROCHESTER, MINNESOTA

ALMOST every day new accounts are to be found of airplanes that excel in speed or will reach altitudes unthought of a year ago. The word substratosphere is in the common vocabulary and we concede the aeronautic and engineering sciences almost no limit of accomplishment.

Scientific interest in the physiologic problems of flight has been rather sporadic throughout the history of aviation.



Courtesy of H. G. Armstrong
NITROGEN BUBBLES IN VEINS
OF EXPERIMENTAL ANIMALS, PRODUCED BY RAPID
ASCENT TO HIGH ALTITUDES.

The universal and time-worn method of trial and error has usually been employed, and only after some major misadventure has the problem gone to the laboratory for solution. Paul Bert was stimulated, in part, in his experimental studies of the effects of low barometric pressure on the body by the unfortunate and bizarre stories related by the balloonists of that time. Trained scientists and laboratories were not available during the past war until appalling tragedies in flying commands made studies of flying personnel and the physiologic problems involved of paramount necessity. Likewise, commercial air lines paid little attention to the physiologic problems of flight until frequently recurring disasters forced them to seek aid in solving the physiologic problems of the human machine in the air.

The constant achievements of the aeronautic and mechanical engineers have created and are creating new physiologic problems. A race is in progress between the engineers and the physiologists, with the engineers setting the pace. We are inclined to accuse them of building a machine to transport man but on the completion of the machine finding that man can not take full advantage of its performance and that he was not seriously enough considered during the building process. It is the great performance of present-day aircraft that creates abnormal environments for man; high speed, rapid climb, steep descent, centrifugal forces, long intervals of flight, high ceiling with its

environmental changes such as cold, glare and low oxygen pressure, and finally, great changes in barometric pressure. It is the problem caused by the rapid decrease in barometric pressure in ascent to high altitudes that we wish to discuss in this paper.

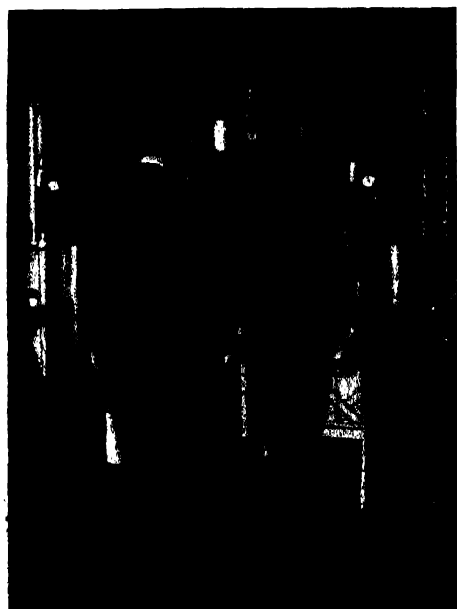
Boycott and Haldane, in 1908, first mentioned the possibility that caisson disease (air embolism) might develop in aviators if too rapid an ascent was made. They based their opinion on the fact that the blood and tissues of the body are always fully saturated with atmospheric gases at sea level since the blood in the lungs is exposed to these gases and each is in solution according to its partial pressure. Nitrogen, which is physiologically inert, and hence not utilized, is taken up in physical solution by the blood in the lungs in relatively large amounts because of its high partial pressure (approximately 79 per cent. of an atmosphere) so that at sea level the nitrogen in the blood is in saturation equilibrium with the nitrogen in the alveolar air at a partial pressure of approximately 560 mm $[(760-47) \times 0.79]$.

Armstrong, working on physiologic problems of aviation, has demonstrated the occurrence of air emboli during experiments in a low pressure chamber and has called the condition *aeroembolism*; he defines it as a disease produced by a rapid decrease of barometric pressure below one atmosphere, such as may occur in airplane flights to high altitude. The disease is characterized by the formation of nitrogen bubbles in the body fluids and tissues and its causative factors are fundamentally the same as in the case of bends or air embolism in deep sea divers or caisson workers. If, in flight or in a low pressure chamber, the pressure is reduced from 760 mm to 150 mm, approximately equivalent to an altitude of 38,500 feet, the same effect would be produced as by surfacing a diver from

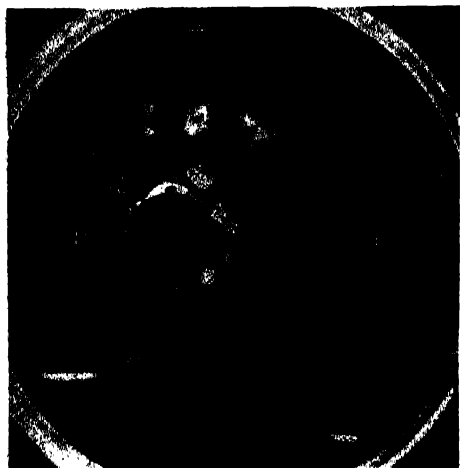


PRESSURE CHAMBER
WITH TECHNICIAN AT CONTROLS OBSERVING AND
TALKING BY TELEPHONE TO SUBJECTS INSIDE.

an excess pressure of four (total of five) atmospheres after he had been at that depth long enough for his blood to be saturated with nitrogen at the increased pressure.



EXERCISING ON TREADMILL
AT TWO MILES PER HOUR, WHILE BREATHING 100
PER CENT. OXYGEN WITH BOOTHBY, LOVELACE,
BULBULAR INHALATION APPARATUS.



ANALYZING ALVEOLAR AIR

METHOD OF OBTAINING AND COLLECTING SAMPLES TO CHECK AMOUNT OF OXYGEN REQUIRED PER MINUTE WHEN USING THE B. L. B. APPARATUS.



INSIDE THE CHAMBER

OBSERVATIONS BEING MADE BY THE TECHNICIAN ON A SUBJECT LYING DOWN; BOTH ARE OBTAINING OXYGEN BY USE OF THE INHALATION APPARATUS.

Whenever the atmospheric pressure is decreased, as during the ascent of an airplane, the partial pressure of nitrogen in the body fluids and tissues is obviously greater than that of the nitrogen in the air of the alveoli of the lung, and the tissues, therefore, are temporarily supersaturated. Consequently, in an effort to equalize the pressure, the nitrogen dissolved in the blood begins to be given off in the alveoli of the lungs and the nitrogen in the tissues begins to enter the blood stream. When the ascent or decrease in the barometric pressure is sufficiently slow that the nitrogen in the body can be eliminated and its concentration does not exceed somewhat less than double its normal saturation at the given altitude, nothing unusual will happen. However, when the concentration of nitrogen in the body attains, approaches or exceeds more than double its normal saturation value at any altitude-pressure, the nitrogen gas will tend to come out of solution and form bubbles. It has been demonstrated that the bubbles are formed, not only in the blood but also in the tissues and other body fluids. The

tissues which have the highest fat content are the most favorable site for bubble formation since nitrogen is more soluble in fats and oils than in water, as found by Vernon in 1907 and confirmed by Campbell and Hill in 1931.

The normal nitrogen gas content of the body (not to be confused with organic nitrogenous compounds) is usually estimated as being about 1,000 cc under normal conditions at one atmosphere's pressure; sea level. Burns gave the following figures for the nitrogen content of a man weighing about 155 pounds (70.3 kg): Total of 995 cc distributed in blood, 30 cc; fat, 530 cc; bone, 0 cc; residue, 435 cc. It has been shown that the blood and other body fluids contain about the same quantity of nitrogen as would water under similar conditions of temperature and pressure. However, on analysis it has been shown that bone marrow contains about 5 cc of nitrogen per 100 cc of tissue and the brain tissue contains 1 cc of nitrogen per 100 cc of tissue. The greater solubility of nitrogen in fatty tissues is of importance in the elimination of nitrogen from the

body and in the symptoms of air embolism.

The symptoms of aeroembolism, just as the symptoms of caisson disease, depend primarily on the location and size of the nitrogen bubbles that are formed. These bubbles, when in the blood vessels in sufficient size and number, cause a mechanical obstruction of the blood flow and deprive the tissues of their normal blood supply with resultant sudden and severe anoxia. When the bubbles are small and numerous they may lodge in the capillaries of the lungs and, by their mechanical interference with the pulmonary blood flow, cause minute pulmonary emboli; this filtering, however, may protect the cerebral centers. The solubility of nitrogen in tissues with a high fat content and relatively poor blood supply, such as the spinal cord, makes this a frequent site for bubble formation with paralytic symptoms.

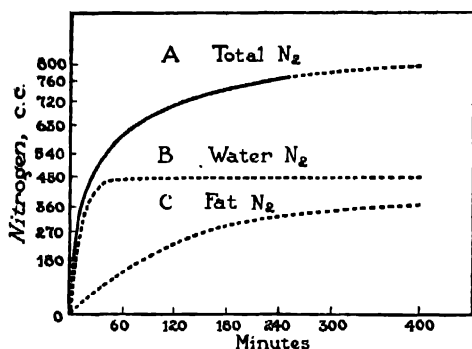
Armstrong has described the various symptoms of aeroembolism in the order of their occurrence as follows: pain about the joints which may be quite mild at the onset but soon becomes gnawing and boring in character, and finally becomes so painful that relief is sought; pruritus of the skin and eyelids and formication; abnormal thermal sensations of hot or cold; cutaneous erythema and often urticaria, and localized pain in the nerve trunks or neuritic pain in the peripheral nerves as a result of formation of bubbles in the myelin sheaths.

The small joints of the hands and wrists are most commonly involved, but shoulder, ankle, hip and other joints may be involved. Emboli to the lungs may plug up numerous small blood vessels, and finally a large region may be deprived of an adequate blood supply, the blood vessels of the lungs acting as a sieve to a certain extent. With bubbles (emboli) in the lungs there may, at first, be a burning pain and, as the condi-

tion progresses, the pain becomes finally sharp and stabbing. Edema, or fluid in the lungs, may develop, which results in paroxysms of coughing.

We have observed mild symptoms, suggesting the formation of small air emboli to occur at 18,000 feet, a pressure of one half atmosphere, after rather slow ascents, around 400 feet per minute. However, Armstrong and associates consider 30,000 feet to be the critical altitude after a rate of ascent of only 200 feet per minute. They describe the time of onset of symptoms as being somewhat variable, subject to individual variation, speed of ascent and final altitude or pressure reached. Symptoms may appear within five minutes after a sufficient altitude has been reached, or their onset may be delayed for several hours. Tunnel workers or "sand hogs," as they are called, often wear distinctive tags about their necks so that they may be identified and properly treated if severe bends develop hours after they emerge from the caissons. Obese individuals are possibly more susceptible than thin muscular individuals.

Pfütger early showed that nitrogen was removed from the blood of a dog when the animal breathed gas without nitrogen, and Paul Bert (1878) first tried the administration of pure oxygen to animals under excess pressure in order to prevent the development of caisson disease. However, the method generally employed in decompressing divers was the stage method as developed by J. S. Haldane. This consisted of bringing a diver to the surface by stages; the purpose of the stages or stoppages at various levels being to allow the excess nitrogen in the body to be given off and equilibrium to be nearly reached between the nitrogen of the inspired air and the tissues. This method was found to be fairly effective but very slow, and is



Courtesy of Behnke, A. R.

CHART OF NITROGEN ELIMINATION

SOLID LINE SHOWS NITROGEN ELIMINATION FROM A YOUNG, WELL-DEVELOPED MAN WEIGHING 60 KG WHEN PURE OXYGEN IS BREATHED. DOTTED LINES SHOW RATE OF ELIMINATION OF DISSOLVED NITROGEN IN MAN FROM WATER AND FAT RESPECTIVELY.

obviously too slow to be of value in aviation.

Hill (1912) and Bornstein (1913) demonstrated that, by breathing oxygen, nitrogen could be eliminated from the body. Recently, Campbell, and L. Hill and Behnke have contributed valuable quantitative data with reference to the total nitrogen in the body and its rate of elimination while breathing essentially 100 per cent. oxygen. They found that, with the subject at rest, 95 per cent. of the total nitrogen is eliminated in four hours, and approximately 99 per cent. in six hours. Although half the total nitrogen is eliminated in approximately forty minutes, it must be noted that at least eighty minutes are required for half the nitrogen to be eliminated from the fatty tissues.

The inhalation of 100 per cent. oxygen reduces the partial pressure of nitrogen in the inspired air to practically zero as the nitrogen in the lungs is quickly washed out. As a result, the nitrogen in the blood passing through the lungs diffuses into the alveoli and is expired, since gases always diffuse from a region of high pressure to one of lower pressure

of that particular gas. In a few minutes most of the nitrogen in the blood will be eliminated. However, the blood in its passage through the tissue capillaries will take up additional nitrogen, carry it to the lungs, and there give it off. The tissues with a high fat content are commonly relatively avascular, and hence give up their nitrogen rather slowly and account for the long period of time required to free the body entirely of its nitrogen. Exercise while breathing oxygen in the decompression of divers was early advocated by Haldane and Priestley to accelerate the circulation and hasten the removal of nitrogen.

Our immediate interests and experimental efforts have been centered on perfecting a method or methods of rapid and effective nitrogen elimination. It is evident from the foregoing discussion that the inhalation of 100 per cent. oxygen is the most effective and practical method of eliminating the nitrogen by establishing a high diffusion pressure head from tissues to lungs. Exercise with its concomitant increase in the circulation rate while breathing oxygen offers the best method known at present to eliminate the store of nitrogen of the body in the shortest interval of time.

To date we have made 102 ascents to 30,000 feet, eighty ascents to 35,000 feet and thirty ascents to 40,000 feet in a low pressure chamber. The rates of ascent have varied from 350 feet a minute to 4,700 feet a minute. The subjects have remained at the peak altitude (35,000 feet) for as long as two hours and fifteen minutes, although it has been more usual to maintain the highest altitude from ten to thirty minutes.

Several of the slower ascents were made without preliminary nitrogen decompression in the earlier experiments, but all recent observations have been made after the subjects had breathed essentially 100 per cent. oxygen making

use of the B.L.B. inhalation apparatus both sitting at rest and exercising *in situ* or on a treadmill. The subjects have been supplied with oxygen in adequate amounts up to 33,000 feet while in the low pressure chamber to avoid the symptoms of anoxia and to maintain the low nitrogen pressure on the alveolar side of the pulmonary membrane; above this level even pure oxygen will not maintain a normal alveolar oxygen, and at 40,000 feet the subject has an average alveolar oxygen pressure of only 56 mm instead of the normal pressure of 100 mm at sea level.

We have considered symptoms such as "light-headedness," smarting or stinging of the conjunctiva, formication and fleeting joint pain as suggestive symptoms of air embolism. Aching pain in the extremities and joints, stabbing chest pain and incessant non-productive cough are believed to be quite pathognomonic, especially if they begin suddenly and become progressively more severe at the higher altitudes only to subside at lower altitudes. We have observed the symptoms enumerated, and on one occasion two subjects, who breathed pure oxygen for only twenty minutes at rest, ascended to 40,000 feet in fifty-four minutes (722 feet per minute). At this height one of them experienced severe aching pain in the right third and fourth interphalangeal joints and metacarpophalangeal joints. The other subject complained of a neuritic type of pain in his arm and found that exercise had to be stopped because of excessive fatigue. Immediate descent to 30,000 feet caused the symptoms to disappear except for weakness in the arm in the subject having the neuritic pain at the higher level. Even the "fatigue" of the arm subsided soon after the ground level was reached.

In another experiment a paroxysmal non-productive cough developed in one of the subjects at 40,000 feet after he

had given an alveolar air sample. He had been insufficiently decompressed prior to the ascent. The non-productive cough persisted for about two hours after descent, and there was a generalized soreness of the entire chest for the next twenty-four hours.

Premonitory symptoms of air embolism have been observed as low as 20,000 feet after a rather slow ascent when no preliminary decompression was employed. These symptoms consisted of stinging of the conjunctiva, formication and abnormal cutaneous thermal sensations.

With the data discussed, but in the absence of more quantitative data, we are able to state that we have not observed symptoms of air embolism, in either rapid or slow ascents to altitudes as high as 40,000 feet, if 100 per cent. oxygen was breathed for forty-five minutes or longer at rest or if exercise, while breathing pure oxygen, was performed on the treadmill at a rate of two miles per hour for twenty minutes or longer. It must be stated here, however, that the time spent at the high altitudes prior to the onset of symptoms is a variable factor, and that it is well recognized in diving operations that some individuals are particularly susceptible and others refractory to the formation of air emboli. Quantitative studies on the rate of nitrogen elimination while breathing pure oxygen under varying conditions of exercise and the percentage of the nitrogen in the body that must be eliminated to prevent embolism should yet be fully ascertained. Such studies are in progress.

The treatment of air embolism, once it has occurred, is recompression. In the case of the diver it means return to an increased barometric pressure, while in that of the aviator it consists of descent to a lower altitude where the atmospheric pressure is greater. The increase in

pressure will result in a reduction of size of the nitrogen bubbles that are causing the trouble. Complete elimination of bubbles is, however, a slow process because the recompression reduces the size but does not remove them from the tissues and the blood. The bubble, in addition to its surface energy, reaches equilibrium with the gases in the surrounding media. Boycott, Damant and Haldane demonstrated bubbles in the blood stream of a goat two days after decompression, and in the spinal cord ten days after decompression. It has been found that 100 per cent. oxygen should be inhaled in addition to the recompression to allow the nitrogen of the bubbles to diffuse out completely, as demonstrated so well by Behnke and Willmon, who had the divers that participated in the salvage and rescue operations of the *U.S.S. Squalus* breathing pure oxygen by means of the B.L.B. inhalation (7) apparatus during recompression after rapid ascent.

The hazards of aeroembolism are especially important in military aviation because tactical considerations of high altitude flying necessitate a very rapid rate of ascent. For instance, the chief function of an interceptor-fighter airplane is to reach a high altitude as rapidly as possible on air raid alarm in order to engage in combat with the enemy before they can accomplish their mission, which may be bombing or observation. For tactical effectiveness against an enemy plane with a cruising speed of 300 miles per hour at 30,000 feet, an interceptor plane must be able to reach this altitude very quickly, since in ten minutes' time the enemy aircraft will be 50 miles nearer its objective. The pilots who are on call for these pursuit missions in time of war, if the intelligence net be far enough out (forty minutes), can rapidly eliminate the greatest proportion of their body nitrogen by breathing oxygen and

exercising for twenty-five minutes. In the event of only ten minutes of advance intelligence, as may be the case in active aerial warfare, the squadron crew should come on duty twenty minutes before actually taking over and breathe pure oxygen while at the same time exercising by stationary running. They will thereby desaturate their bodies of nitrogen and make it safe to climb immediately into their planes and take full advantage of a rapid rate of climb.

Test pilots of the large airplane factories at the present time, no doubt, subject themselves to the dangers of aeroembolism in their tests of high performance airplanes. Proper facilities for preventing accidents of this nature should, of course, be provided.

Essentially 100 per cent. oxygen has been administered to more than 2,000 patients for as long as twenty-four hours with no evidence of ill effect. Helium-oxygen mixtures have been used with great success in decompressing divers in very deep diving operations, but the use of helium for this purpose in aviation offers no advantages, and might even complicate the procedure.

The use of pressure cabin airplanes is coming into vogue, and the pressurized suit has been used in several record altitude ascents by heavier than air machines. They can maintain any predetermined internal pressure, and hence insure an adequate partial pressure of oxygen and protect the occupants from marked changes in barometric pressure, a valuable consideration from the standpoint of the middle ear. However, as very high altitudes are reached, a marked pressure differential is established between the suit or cabin and the surrounding atmosphere. A failure of the cabin or leak in the suit means a sudden explosive decompression, the severity depending on the pressure differential,

with sudden oxygen want and, probably worse, the likelihood of severe aeroembolism. Partial nitrogen decompression prior to ascent in the pressure cabin or pressure suit would appear to be advisable if high altitudes are to be reached and a relatively high pressure differential is to be maintained.

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A NEW WORLD?

LOOKING at the facts immediately before our eyes, there is abundant reason to feel that 1940 may go down in history as one of its darkest pages. This is the year in which we have witnessed the fall of most of the democracies of Europe. It is the year in which we see Great Britain fighting heroically for her life. It is the year in which human freedom everywhere is in mortal danger. Yet if this remaining fortress of democracy across the sea holds out and eventually conquers, what has passed may turn out to be only an evil, tragic dream, that will be dissipated in the dawn of a better day.

For it is not impossible that history may record the most momentous happening in 1940 as having taken place in the laboratory rather than on the battlefield. I am thinking that the truly epoch-making event of the year may be man's first successful attempt to release atomic energy, through the isolation of Uranium 235.

The importance of this new discovery lies in the fact that a natural substance, existing in comparative abundance, has been found capable of releasing energy on an unbelievable scale. The isolation of that substance is an exceedingly difficult process, but—in laboratory quantities—it has now been accomplished. A single pound of Uranium 235, it is said, will provide the energy equivalent of three million pounds of gasoline or five million pounds of coal. The utilization of that energy, once the substance is

available in commercial quantities, becomes a practical matter.

Scientists are hopeful that a method of isolating UR 235 in large quantities can be developed. I have learned from long experience to have more faith in the scientist than he has in himself. Experience and faith tell me that—given time, facilities and freedom to follow where imagination leads—the scientist will do all he hopes to do, and more.

What coming generations may be able to see with their own eyes and judge from their own experience is to-day almost beyond the scope of our imagination. With atomic power, people may be able to light, heat, ventilate and refrigerate their homes with ease and at trifling expense. Ships, railway trains, automobiles and airplanes may be fueled for life at the time they are built. Men may carry in their pockets personal radio telephones which will enable them to communicate throughout the world. A myriad of new products and services will become available to all. Many of the old hardships and deprivations—the sources of social and economic unrest—will disappear. A new society, dwelling in a new economy of abundance, will be born.

Is all this a dream? Yes, but it is the dream stuff of science, and our dreamers are the scientists who are opening new vistas for civilization. —David Sarnoff.

THE BIMILLENNIUM OF THE BIRTH OF AUGUSTUS CAESAR

AN ESTIMATE OF HIS WORK AND CHARACTER

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THE year 1938 marked two great anniversaries, one important to us Americans, the other to world history. On June 21st we celebrated the birthday of a great democratic ideal, for on that day one hundred and fifty years ago New Hampshire cast the enabling vote for the ratification of our Constitution, at once the fountain-head of our liberties and the supreme law of our land. On September 23rd two thousand years ago Augustus Caesar, founder of the world's most important empire—that of Rome, was born, an anniversary which was celebrated in most of the universities of the world wherever ancient history is taught. His advent meant not only much to the world of his day, but also to ours, since out of his creation have come the political ideas, traditions and largely the culture of our time; for the Roman Empire still lives in its language, literature, municipal system, imperial idea of church and state, and in many less obvious ways still influences our thought and life. It is fitting, therefore, that we review the career of its founder and glance at the world into which he was born and that which he left.

By his victory at Actium in 31 B.C., Octavian, the future Augustus, ended the century of revolution and civil strife at the close of the Roman Republic, and ushered in an era of prosperity and peace for the Mediterranean world which lasted two hundred years. The Roman world lay exhausted in the hands of one able and fortunate enough to remodel its fragments into an enduring state. It was indeed a great work to organize out

of chaos and anarchy a splendid mechanism of orderly government which with modifications stood for centuries. In the words of Merivale, the historian of its first two centuries: "The establishment of the Roman Empire was after all the greatest political work that any human being ever wrought. The achievements of Alexander, of Caesar, of Charlemagne, of Napoleon are not to be compared with it for a moment." Haverfield, the historian of its westernmost province, Britain, has said: "No empire has left so great a name as Rome. None has so thoroughly conquered its barbarian conquerors and set so deep a mark on the memory of succeeding generations." Of its tragic passing none has spoken so feelingly as Professor J. S. Sheppard in his "Fall of Rome and Rise of New Nationalities"—though "fall" is misleading, since it involved no catastrophic governmental collapse, but merely a regrouping of its parts: "No event, perhaps we should rather say no series of events, in the secular history of mankind, can equal in interest the fall of the Roman Empire. Our minds are overwhelmed by the grandeur of the image which the name of Rome evokes. Throughout all the mutations of human affairs and the vicissitudes of what men call Fortune *magni stat nominis umbra*. The giant shadow broods over the birth of European civilization and projects itself into the depths of an unknown future. As on Rome all ancient history converges, so from Rome all modern history begins." And Gibbon, author of its decline, more tersely spoke of its pas-

sing as "a revolution which will ever be remembered and is still felt by the nations of the world." And we should remember with Hodgkin, the historian of its barbarian invaders, that "when Rome ruled she was not only the greatest but practically the only Power of which the statesman and the philosopher took any cognizance."

Long before Caesar's assassination on the memorable Ides of March in 44 B.C. the Roman Republic had waned chiefly because of internal troubles caused by her conquests. Democracy in Rome really ended when she ceased to be a city-state, for in antiquity, largely because of the lack of easy communication and newspapers, democracy could only exist in small areas. Throughout the long era of expansion from the First Punic War to the end of the Third—264-146 B.C.—Rome had conquered most of the countries in which the main current of history had theretofore run its course, and had found herself a world state. Her great problem was how to administer so colossal an aggregation of peoples and lands with her inadequate machinery of Republican government. The Senate continued to rule because it alone knew how to rule. But soon after the fall of Carthage and Corinth in 146 B.C. its power was disputed and this lasted for over a century when all sorts of problems, political, social, economic and military, were raised but not answered. Wealth had come through conquest and its accompanying slavery and not through agriculture nor industry.

Beginning with the tribune Tiberius Gracchus in 133 B.C. a line of "super-men" arose, who in various ways tried to cure Rome's ills only to become in turn virtual dictators—Caius Gracchus, Marius, Drusus, Sulla, Pompey, Caesar, Antony and Octavian. In fact, the last century of the Republic marks its death-struggle and the birth of a new era. One of its most dangerous features, inaugu-

rated by Marius, the savior of Rome against the Cimbri and Teutones (102-101 B.C.), was the turning of the old national militia into a voluntary professional army interested far more in its commander than in the state for spoils and so became a public menace. By Pompey's time he could boast that he needed only to stamp his foot and armed men would spring from the soil of Italy to do his bidding. Julius Caesar soon after the First Triumvirate (60 B.C.) engaged him in civil strife and, when successful, instituted far-reaching reforms in the Constitution, but his efforts only led to his assassination before he had completed his work, and Rome lost the "one original genius of her history."

Julius Caesar has indeed left an indelible stamp on history and "did bestride the narrow world like a Colossus." Schoolboys still puzzle over his commentaries on the Gallic War—a conquest among the greatest in their results, whatever we may think of the morality of an undertaking which caused the death of perhaps a million human beings and the banishing of liberty from a huge area; historians still study his career and generals his battles; and kings emulate his example, his very name their proudest title—Kaiser or Czar. But despite all he did perhaps his best epitaph is this of Professor Adcock: "Caesar had done much for the state in his reforms, but he did no greater service than by his death." Still his assassination was no stroke for freedom as the liberators had imagined, but one of the most futile acts of antiquity—for it struck a wise ruler and not the monarchy which was inevitable. His death caused the Roman world untold suffering for nearly fourteen years—proscriptions, civil war, the mad rule of Antony and despair, until Octavian, a man of far lesser mould, got rid of his rival Antony and restored and improved upon the system Caesar had inaugurated.

Only confusion followed the act. Caesar had made no provision for a successor and the conspirators no plans to take over the government or how to deal with Caesar's lieutenants, Lepidus, his master-of-horse, or Antony, the surviving consul. Cicero, who favored the conspirators, since his whole policy was to save the Republic, in a private letter said in slaying Caesar they showed the political sagacity of babies. They soon found their act met only ominous silence when Lepidus and his troops seized the Forum and Antony seized the papers and money of Caesar, and they soon took refuge on the Capitol. They had learned too late that though Caesar was dead his party lived on in his veterans and the mob now led by Antony, a past-master of political chicanery. He at once took advantage of the crisis and used every device to appear as Caesar's successor. He soon convened the senate, a majority of whose members favored the liberators, but, induced by Cicero, it voted a general amnesty and at the same time the ratification of Caesar's acts and his public funeral. Antony mounted the *Rostra* and delivered a stirring eulogy over the dictator's body, his violent rhetoric and display of Caesar's toga rent with dagger thrusts so inflaming the populace that they forthwith burned Caesar's corpse in the Forum and fired the liberators' houses. Cleopatra and her son Caesarion by Caesar left the city for Alexandria, where we shall meet them again; and soon the arch-conspirators, Marcus Brutus and Cassius, hurried east to the provinces assigned to them by Caesar—Macedonia and Syria respectively—to collect men and treasure for the inevitable struggle with Antony.

Two months after Caesar's death Antony found a redoubtable rival to his plans in the person of the dictator's grand-nephew, Caius Octavius, whom in his will Caesar had adopted and made heir of three-fourths of his estate. He

was now a youth of eighteen, studying with his boyhood friend Agrippa in Epirus and there awaiting Caesar's arrival to accompany him on his proposed Parthian expedition. By the end of March he had learned of the murder and at once, despite the warnings of friends, crossed the Adriatic, and by the beginning of May reached Rome, where he demanded of Antony his uncle's property with which to pay the latter's legacies, and also declared his intention to avenge his death. But the latter, who had already dissipated much of the money he had received from Caesar's widow together with the public treasure which he had seized from the temple of Ops, refused and so began the long enmity, which with short intervals of outward friendship filled the pages of Roman history till Antony's death. Cicero now supported Octavius and denounced Antony in his savage "Philippics" until he drove him into Cisalpine Gaul. With the money he could raise by selling Caesar's real estate and contributions from friends and relatives the ambitious youth paid off Caesar's legacies and so gained immediate popularity.

Octavius now even made advances to the liberator party, and no one can withhold from him admiration for the adroitness with which he went on with his purpose. Supported by two legions which had come over to him, he induced the senate to name him praetor at the close of 44 B.C. and send him with the consuls for the next year to attack Antony, who was besieging Decimus Brutus in Mutina, since the latter refused to surrender to Antony the province of Cisalpine Gaul already assigned to him by Caesar. The consuls raised the siege, but were slain in battle before the walls, and Antony fled over the Alps in April, 43 B.C., where he was soon followed by Lepidus. Cicero, now suspicious of Octavius' motives, induced the senate to keep him from acquiring further

power. Nothing daunted, Octavius with the troops of the slain consuls marched on Rome—from which Cicero retired—and forced his election as consul. It was now also that he was formally adopted into the Julian *gens* by a *lex curiata* and that he added his uncle's name to his own—Caius Julius Caesar Octavianus. His first act as consul was to get the assassins condemned *in absentia*, and then he hurried north to meet the troops of Antony and Lepidus, now returning over the Alps.

Instead of a clash, however, the three leaders met near Bononia, and laid plans for their future aggrandizement. They got the senate to name them *Triumviri reipublicae constituendae* with dictatorial powers for five years *i.e.*, to restore the state. This—the Second Triumvirate—therefore was a different coalition than the preceding one formed in 60 B.C. by Caesar, Pompey and Crassus, for while that was merely a private political ring formed by Rome's then three most powerful men to further their personal ends, this had official sanction. At Bononia they also planned to attack Brutus and Cassius in Macedonia and cemented their union by blood, the terrible proscription of November and December, 43 B.C., one with hardly a parallel in ancient history. Among the chief victims of the butchery was Cicero, whose death Antony demanded and Octavian allowed. His dis severed head was exhibited on the *Rostra* where Fulvia, Antony's brutal wife, gazed upon it with joy and pierced the orator's tongue with a golden bodkin. The scenes which had accompanied Sulla's return to power forty years before were now reenacted, when 130 senators, 2,000 knights and many commoners were slain before opposition was crushed. The three also divided the western provinces among themselves, Octavian to have Sicily, Sardinia and Africa, Lepidus Spain and Narbonese Gaul, and Antony the rest.

Antony and Octavian now crossed the Adriatic and defeated the liberators in the two battles of Philippi in Macedonia in 42 B.C. where a century later Paul first preached in Europe the gentle gospel of Jesus. The Republic was now doomed and Brutus and Cassius committed suicide during the battles. Now the Roman world was again divided on a grander scale, for Octavian took most of the Latin West and Antony the Greek East, Lepidus being reduced only to one province, Africa, the ancient territory of Carthage. Octavian returned to Italy to restore order and distribute promised lands to his veterans. It was then that he confiscated the lands of eighteen communities, among which were the farms of the fathers of three poets who later graced his court—Vergil, Horace and Propertius. But war soon broke out between Antony and Octavian, instigated by Fulvia, the chief incident of which was the besieging of Lucius, Antony's brother, in Perusia and its capture in 40 B.C. by famine when three hundred of its defenders are alleged to have been condemned by the victor during the futile plundering of that ancient Etruscan town. But Fulvia's death the same year made a reconciliation possible between the rivals, cemented by Antony marrying Octavian's beautiful sister Octavia, a harbinger, as was thought, of a lasting peace between them.

The years which preceded the final decision between the rivals were wasted by Antony in the East in fruitless campaigns against the Parthians and in his fatal romance with Cleopatra, the Egyptian queen. After Philippi he had proceeded to Greece and Asia Minor to complete the subjection of some of the eastern provinces. In the year 41 B.C. he had summoned certain client kings and princes to Tarsus in Cilicia to answer for their helping the liberators. Among them was the lovely queen, now twenty-seven and in the bloom of her

beauty, her advent marking the beginning of Antony's downfall. She came, her only defense against her accuser being her personal charm. She ascended the Cydnus in a gilded barge with sails of purple silk and oars of silver; beneath rich awnings the lovely queen reclined dressed as Aphrodite among her attendant Nereids and Loves. Antony succumbed to her beauty and talents, forgetful of country or honor, and the two spent nights and days in banquets and revelries, she amusing him by appearing as Aphrodite or Isis, and he impersonating the wine-god Dionysus or Osiris. Unchastened she led her accuser back to Alexandria, where, during the winter of 41 to 40 B.C., he forgot all duty.

It was when he was recalled to Italy by the Perusian War, which, however, had ended before his arrival, and after Fulvia's death, that he, for a time forgetting Cleopatra, became reconciled with Octavian, late in 40 B.C. marrying his sister. On his return to Asia the next year, he began his attempts to subdue the Parthians and spent some time in Athens with Octavia as a model husband, though his extravagant behavior there, especially by assuming the attributes of Dionysus, overrode Roman sensibilities. In 37 B.C. he returned to Italy for the last time to renew the Triumvirate, and, on his return once more to the East, he sent Octavia back to her brother and resumed his relations with Cleopatra, soon thereafter formally marrying her at Antioch, even though Octavia was not yet divorced. By this act, he publicly renounced all friendship with his rival.

Reports of Antony's un-Roman acts and especially his ill-treatment of Octavia, together with alarm at Cleopatra's rumored intention to form with him a Graeco-Oriental state, aroused indignation at Rome and soon the climax came. The Triumvirate ended in 32 B.C., and

the senate was functioning once more. Octavian, at last ready to crush his rival, having received an oath of fealty from the senate and the western provinces and having published Antony's will—or a forgery of it—in which he disposed of the eastern provinces to the Egyptian throne, easily induced the senate to declare war on Cleopatra, thus avoiding the name of a civil war with Antony. The latter now divorced Octavia, who, however, proved herself one of the noblest of Roman matrons, for instead of resenting his insults she, after Antony's death, reared his children by both Fulvia and Cleopatra along with her own down to her death in 11 B.C.

Finally, on September 2, 31 B.C., the West again faced the East as it had done already at Philippi and Pharsalia, this time in the greatly overrated sea-fight off Actium on the west coast of Greece, hardly a battle at all, as it was attended by the treason and early flight of the chief combatant. Here Agrippa blockaded Antony's fleet in the harbor, though it outnumbered his own two to one, and cut off the land army from supplies. In the midst of the ensuing battle Cleopatra's fleet of sixty galleys, posted in the rear and carrying Egyptian treasure, sailed away for Egypt, and a little later Antony, seeing only defeat, followed, abandoning his fleet and army. But the tradition that the queen betrayed him and then received him on board her flagship after he had left no commands for his officers seems to be a fiction circulated by the victor's party, for Antony's version has never been told. His army surrendered without a blow and was forgiven by Octavian, who thus exhibited his first example of humanity in the long duel now ended.

Antony, now a rebel and fugitive, soon reached Egypt, where the last act of the tragedy was played. Knowing that Octavian would follow him, even as Caesar after Pharsalia had followed Pompey,

Antony tried to raise troops against him. Octavian, after spending the winter of 31-30 B.C. in settling the eastern provinces so badly neglected by Antony, reached Egypt early in 30 B.C. and besieged the queen and her lover in Alexandria. Seeing the desperate fortunes of Antony, Cleopatra negotiated with Octavian for his death, and entering her mausoleum caused the report of her own suicide to reach Antony who, unwilling to survive her, stabbed himself, insisting on being drawn up into the mausoleum by a rope, where he perished in her arms. The queen, after vainly attempting to move the passion of Octavian, as long before she had moved that of Caesar, took poison rather than live to grace the conqueror's triumph, and thus, at thirty-eight, ended the three centuries of the Greek rule of the Ptolemies over the land of the Pharaohs. Egypt, because of its importance as a granary, was kept from partisan leaders and ruled directly by Octavian as a private domain through a prefect. Other rivals there—including Caesarion—whom in 42 B.C. the triumvirs had allowed to receive the title of King of Egypt and who in 34 B.C. had been called King of Kings by Antony—were slain and finally the Roman state had a single master. Octavian, the last of the long line of supermen who had struggled for mastery, had won.

It was to the best interests of Rome that Antony, a curious mixture of sentimentality and cruelty, personally attractive but without positive virtues, should have lost to his colder rival. Legend has laid his failure to infatuation for a beautiful woman who is still a kind of enigma, since her coin-portraits do not bear out the tradition of her loveliness. But the truth seems different. His armies left him, their Roman spirit outraged when they learned that he intended to dismember the Roman state and with her found an empire with Alexandria as its

capital. The legend circulated by Plutarch, who made the death-scenes of the "inimitable lovers" immortal in literature, came from Octavian's party. The truth is Cleopatra hoped to rebuild her crumbling fortunes through Antony, the best general of his time, but chose the wrong man. When she found Octavian would not be so used, suicide alone was left for this mistress of luxury and pleasure. On Antony we quote from a recent book by Professor Glover: "he might well be forgotten had not Plutarch written of him and Cleopatra and had not Shakespeare read Plutarch in English and written a play, . . . and all the way Shakespeare follows Plutarch, only (as Heine wrote) adding genius. To that play too the reader will turn and will understand why Augustus and not Antony ruled the world. Antony in truth belongs to literature far more than to history."

Octavian had made good his claim to Caesar's heirship. The Roman state, now weary of war, regarded him as a savior and creator of a new era—the Augustan Age. He reached Rome in 29 B.C., when his brother consul offered sacrifices for his safe arrival, an unprecedented honor. In August he celebrated his triple triumph for victories in Illyria, Greece and Egypt. On the first day Gallic and Illyric captives marched; on the second the beaks of Antony's ships were displayed with Asiatic princes, once his allies, bound with golden chains; and on the third Cleopatra's twins by Antony, now eleven years old and so too young to feel their disgrace, marched amid the Egyptian spoils and the effigy of their mother borne on a litter. But now, as in Caesar's quadruple triumph celebrated seventeen years before, no Roman was led captive. Octavian now was undisputed master of Rome; regarded by Greeks and Orientals as a God to whom temples of *Rome and Augustus* were later erected, an imperial cult kept

up as a focus of patriotism; ruling in Egypt as the successor of the Ptolemies, as these had been of the Pharaohs; and commander-in-chief of fifty legions. The ceremony ended with the dedication of the temple of *divus Julius*, his uncle, and the closing of that of Janus in the Forum—the third time only in the martial history of Rome as a symbol of “the immense majesty of that Roman peace,” as the Elder Pliny called it.

Octavian now, to quote his own words, was “master of all things” and Rome looked to him, the victor, to rebuild the war-torn state into a constitutional government such as had not existed since Caesar crossed the Rubicon twenty years before. He found himself faced with the same problems which had faced his uncle—what sort of government he should institute and how he could fit one-man rule into it without offence to Roman sensibilities. To solve it he had little of the splendid genius of Caesar, “the foremost man of all the world,” neither his patrician outlook as the descendant of gods and heroes nor his willingness to forget the past and build anew. To be sure, Caesar had lived too short a time after his civil war with Pompey was over to show just what style of rule he intended, further than concentrating all executive power in his own person, and not sharing it with the old oligarchy—the senate. Octavian possessed very different qualities which, however, were to win where genius failed—caution, patience to let time shape his course, perseverance and, above all, a sincere love of Rome’s past. With such qualities he could not follow his uncle into abruptly breaking with tradition and, basing his rule on the army, blend Italian citizens with provincials, and let Italy lose her historical predominance, and so inaugurate a new and un-Roman régime.

Every one at Rome knew that monarchy was the only solution of the Re-

public’s ills—those of a state long harassed by factions and civil wars, economic decay, lack of representative government, and withal based on slavery. During the last century mob-rule at times had turned the tribuneship into a dictatorship, and dangers on the frontiers had given undue authority to provincial governors over armies; such experiences had made Rome ready for a monarch—that had already been fulfilled in Caesar—but not for a king or dictator. Octavian knew that his uncle’s fate was largely due to his contempt for Republican institutions and especially to his flouting of the senate; and he knew that the tradition of centuries of democratic rule, from the expulsion of the kings to Caesar’s perpetual dictatorship (509–45 B.C.) could not be obliterated. To succeed, then, he could not follow Caesar’s path which had led only to assassination, for Rome would support him only if he could conciliate tradition and harmonize the new state with ancient privileges and so preserve the old shell. His struggle with Antony, as Caesar’s with Pompey, had shown that the senate was no longer the real issue, for it had interfered with neither, and on his return to Italy was in the same position it had been in back in 44 B.C., unable to recover its prestige or bring order and peace. Therefore it mattered little who should replace it in power, if only that man could restore the ancient unity. Thus he felt that he had no choice except to rebuild and not to destroy the ancient fabric, to cloak his personal rule under Republican forms, since a literal restoration of the past was impossible.

The task before him was indeed immense, and he performed it only gradually, for to conceive on the grand scale and to execute quickly were foreign to his cautious nature. But his final solution of the problem places him securely in the short list of the world’s great statesmen. He must restore peace and prosperity in

Italy and the provinces after the ravages of a century of civil strife; lift the state out of political and economic chaos; regulate the frontiers and, for security's sake, extend them beyond the Alps to the Rhine and Danube; put down piracy and brigandage and relieve Rome from further fear of invasion and revolution; abolish abuses and institute beneficial laws; repair roads and cultivate waste-lands; patronize literature and art and start a program of religious and moral reform; conciliate a senate still possessed of powers accorded it by Sulla, and, above all, keep the affections of a people yet clinging to ideas of popular rule. He lived to do all this and more, and, in a word, became the "architect" of a new order—the Roman Empire.

Finally, in January, 27 B.C., at the beginning of his seventh consulship, he was ready to go before the senate to settle its status and his own in the administration of the future state. He there laid down all the extraordinary powers it had conferred on him in the last few years and declared "the Republic was restored." Thus he surrendered the *imperium* over all armies, provinces and revenues, and all privileges not consonant with the ancient Republican office of counsel, which alone he retained. Two weeks later, January 13, a date thereafter regarded as the birthday of the Empire, the subservient senate voted him back the more essential of his former powers for ten years, proconsular *imperium* over three provinces where armies were still needed—Syria, Spain and Gaul—and reconfirmed his personal rule over Egypt, power which again placed him above all provincial governors, the beginning of the famous "Dyarchy" or "joint rule" of himself and the senate, though there was no question of his predominance in the arrangement. Thus the old military problem of army control, which had injured Rome ever since the time of Marius, was solved, and Octavian be-

came commander-in-chief of all armies with the right of levying troops, an office theretofore only enjoyed by generals in the field. His tribunician power also gave him the right to convene the assemblies as that of consul did the senate, and to veto all legislation both there and in the senate, and he found himself the supreme ruler of the state.

It was at this time that he also received the civic crown to hang over his private doorway in recognition of his having saved the state, and the cognomen Augustus, by which he is best known to history. This title implied no definite powers, but was merely expressive of his almost divine character, for it was the first time it had been conferred on a living man, a title like our "majesty" or "by grace of God." The senate also voted to change *Sextilis*, the sixth month of the ancient Roman calendar, to *Augustus*, as before it had changed *Quintilis* to *Julius*—names which we still use. The title *imperator*, already conferred on him by army and senate after his victory at Mutina in 43, now became his permanent praenomen connoting "commander-in-chief," as well as a title of honor. In the East, where his power was based frankly on the military, it meant more than in the West, where that basis was not emphasized. But he received and asked for no title offensive to Roman feeling, neither "king" which Caesar had coveted, nor "dictator," which he had accepted as a permanent title, though theretofore connoting only a temporary office in crises, nor "censor," which his uncle had taken. He had learned from Caesar's fate the art of holding supreme power without invidious titles, for he had sensed that an undisguised autocracy would only shock Roman sentiment.

Down to 23 B.C. his power at home rested on the annual consulship and tribunician power and abroad on the proconsular *imperium*. In June of that

year the Principate, as we still call the new constitution, received its final form. For now he laid down the consulship which he had shared annually with a colleague since 31 B.C. contrary to all precedent, but retained the *imperium* granted him for ten years in 27 B.C., though it was not valid in Rome. Thus he lost precedence over other magistrates long enjoyed by consuls and the right of convening the senate or holding assemblies. However, the loss was soon made up to him by the senate, which the same year made his *imperium* equal to that of consuls in Rome, and the following year gave him equal rights with the consuls in convening the senate, and in 19 B.C., outward equality with them by allowing him twelve lictors and a seat between those of the consuls. The significance of the extension of tribunician power year by year for life is shown by his dating the years of his further rule by it. In 36 B.C. he had received the tribunes' inviolability, and in 30 B.C. the right to offer aid, and now enjoyed the permanent right to veto legislation. Thus his supremacy was based on two pillars of power—proconsular outside Italy and tribunician inside, which made him a virtual autocrat. But the senate, assembly and magistrates functioned, and soon public life again ran in the familiar channels, though the controlling authority was his, now exercised under constitutional forms with the sanction of senate and people. Thus the old Republic, or whatever of it was worth keeping, was restored under the leadership of the *princeps civitatis*, the first citizen of the state. If it be difficult to define such a curious state, perhaps we might follow the explanation of Lord Tweedsmuir, governor-general of Canada, who, in his recent (1937) biography of Augustus, says: "But it is simpler to look upon the result neither as monarchy nor as republic, but as a mixed constitution, a new thing."

Further decrees made his position even more definite. But, in deference to tradition, he held no new office which would have given him openly supreme power, but the gradual accumulation of various offices made his position, though indefinite, known. Thus, in 19 B.C., he was granted the censorship of law and morality; in 12 B.C., at the death of Lepidus, he took over his title of *Pontifex Maximus*, which made him head of the state religion; in A.D. 2 he received his greatest honor, for now, after over thirty years of rule, he became *pater patriae*, which marked the final reconciliation of the *princeps* and the old oligarchy. The last step of all came at his death, when Tiberius, long associated with him in office, became his successor.

Within its frontiers—the Atlantic, Sahara, Rhine, Danube and Euphrates—lay the Roman state as officially adopted by the senate 27–23 B.C. Gibbon introduces the story of its decline with these words: "In the second century of the Christian era the Empire of Rome comprehended the fairest part of the earth and the more civilized portions of mankind." Hodgkin has added: "Even now a monarch who should thus hold all the lands around the Mediterranean Sea . . . would be incomparably the strongest ruler of the world." It was truly a magnificent domain, including all the countries around the fringes of the Mediterranean in the three continents of Europe, Asia and Africa. Under Trajan in the early second century, at its widest extent it extended from York (Eboracum) to Thebes and from Lisbon (Osilipo) to beyond the Tigris and contained a population at least one third of that of the corresponding areas in our day—the one time in history when civilized man of the West was under one rule, that of the Caesars. Beyond its borders to the limits of the earth were realms only reached in the imagination of an Alexander or a Caesar, into which

Augustus, lacking both the will to conquer and the dazzling generalship of Caesar, and wisely staying the restless advance of Rome toward universal dominion which had marked the closing centuries of the Republic, never ventured to enter. It was his own more moderate idea to center all in Italy from the Alps to Sicily as the heart of the vast organism, and to demand from it the soldiers to protect it, fearful lest further drain on Italy's soldiery might imperil its safety at the hands of the encircling provinces.

Historians, in praising Augustus' work and the stability of the empire which he founded, doubtless have exaggerated its greatness—apart, at least, from its unconscious mission of transmitting ancient culture to our time, both that which it received from the older nations which it absorbed and that which it gathered from its own mighty course. During the first two centuries of its life the machinery of government ran smoothly enough (even though Domitian at the close of the first for a time renounced the Dyarchy). Under the Antonines—A.D. 138 to 180—it reached its apex of prosperity, even if some of it was specious, an era which has evoked the encomia of all historians. In fact no ruler who has since sat on a European throne has reached the moral stature and Stoic adherence to the duties of high office attained by Marcus Aurelius, the finest spirit among the emperors.

Then came the appalling crisis of the third century when the emperors were the sport of the legions, a period introduced by Septimius Severus, whose absolutist ideas make him, in the words of Gibbon, "the chief author of the decline of Rome," and followed by the worst half century in the story not only of Rome but of Europe. Further, the process of disintegration ate into the very heart of the state, which offered the pitiful spectacle of a vast moribund organ-

ism torn politically and strangled economically by forces it could not master—anarchy and revolt, division and loss of half its territory, plague and famine, unheard-of taxation and external pressure of the barbarians. Finally, after the heroic endeavors of a Claudius and an Aurelian—whose abilities were worthy of a more fortunate era—the last of the "barrack" emperors, Diocletian, called by Ferrero "the last great man of antiquity," stayed the downward course. But thereafter the empire visioned by Augustus three centuries before was no more, for his restored state, "the Dominate," was an un-Roman absolutism, under which one was master and the many were slaves. The story of its last century after the division of the huge colossus into its eastern and western halves at the death of Theodosius in 395 is a Greek tragedy, its gradual ruin a preparation for a new order—the Middle Ages. For the western half rapidly collapsed till its last vestiges disappeared eighty-one years later, when German kingdoms had occupied all the western provinces; but the more fortunate eastern half ruled from Constantinople, to which Constantine had moved the capital in 330, while proclaiming itself inheritor and continuator of old Rome, lived on another millennium as an Oriental type of medieval state, the "Byzantine Empire" with few Roman features beyond Diocletian's government pattern, till all that was left of it, the capital city on the Bosphorus, long protected by the massive walls of Theodosius II, fell to the Turks in the fifteenth century. This was the last remnant of antiquity projected into modern times.

Nor is it difficult to find grave flaws in the vaunted greatness of the first two centuries. Its greatest defect was the absence of political liberty. Even under benevolent despots man can be happy, as under the good emperors of the second century, as both Gibbon and Momm-

sen have shown. But that happiness depended then as later on the character of one man, sometimes a madman such as Caligula and Domitian, again a monster such as Nero, Commodus or Caracalla, again a religious fanatic as the boy emperor Elagabal, or a sensualist such as Gallienus. Nor should we regard the imperial system even at its best as a monument to political sagacity as older writers did, but rather, in the words of a recent writer, as "one of the most monstrous of all historical examples of graft, corruption and inefficiency," to find the equal of which we are compelled to come down to some of the democracies of our time. Augustus at best only evolved a partially adequate system, for his work was a compromise. There was no approach to scientific government till Diocletian, and then the great days of Rome were gone. For his huge bureaucracy and exploitation of the provinces by ruinous taxation only increased the economic decay, and Rome, in the words of Goldwin Smith, had become merely "a tax-gathering and barbarian-fighting machine." This was one of the major factors along with Christianity which finally brought the fabric to ruin.

Two other defects were inherent in the system from the beginning. Chief of these was the fact that, like modern dictatorships, the state was built around a personality, for Augustus as master of the legions could thwart the senate at will. Augustus certainly overrated the ability of the two corner-stones of his edifice — *princeps* and senate — whose functioning depended on the harmonious cooperation of these two imperial powers, the willingness of the one and the self-restraint of the other. As soon as the senate proved itself incapable, or the emperor abused his power, the entire structure was certain to develop into a military despotism. As a recent biographer has said: "It began with a balance, but whether the emphasis would shift to

princeps or senate only time could show." A no less grave defect was the lack of any law of succession, mainly due to the anomalous position of Augustus himself. Having received his office from the senate, the latter could name his successor or end the office entirely as merely a temporary one. If a legal succession had existed, the grave troubles of 69 after the death of Nero, and those 123 years later at the death of Commodus, when the empire was sold at auction to the highest bidder by the pretorian guard at Rome—the most dramatic and disgraceful event in all history—would have been impossible. That Augustus, however, regarded his office as hereditary is certain, for throughout his long reign he had, in the absence of sons, regarded certain of his household in turn as his heirs; first his sister's son Marcellus, the darling of the populace, whose death at nineteen in 23 B.C. was immortalized by Vergil (*Aeneid*, VI, 861-87) in what have been called "the finest lines ever inspired by untimely death"; then his grandsons Lucius and Caius Caesar, whom he loved, but who died in A.D. 2 and 4 respectively; and lastly his stepson Tiberius by Livia's former husband, the conqueror of Noricum, whom he hated.

Nothing was more characteristic of the real nature of Augustus than his spiritual interests, especially in art and letters. His patronage has given the name "Augustan Age" to subsequent epochs when classicalism has flourished. He followed Caesar's plan of restoring or erecting great public buildings—temples, theaters, porticoes, baths, arches and his own mausoleum—mostly on Greek or Oriental models which he had seen on his travels. In his "Memoirs" he says he "found Rome a city of brick and left it one of marble." But he is more to be remembered for his encouragement of literature. On his age three great poets have shed unfading glory, Vergil, Hor-

ace and Ovid, whose elegant grace and polish made them true offspring of his peaceful reign. Political peace, appreciative patronage, leisure and a cultivated audience as well as inspiration from the older Greek past had all conspired to create a "Golden Age" of letters. Rome's most popular historian, Livy, also graced that court and his "History of Rome," the flower of Latin prose, its style and diction faultless, though it, like the works of the poets of the age, lacked originality so characteristic of Greek letters, has been called "the funeral oration" over the grave of the Republic, for he idealized Rome's past and found consolation for the present in the old Roman ideals. Similarly, Vergil, who had lived through nearly forty years of political disorder only to pass his last years under the Roman peace of Augustus, embellished in incomparable verse the great Roman tradition of Aeneas and the Trojans settling Italy and their descendants founding Rome, and also expressed the ideals of her future. For he gradually became imbued with the splendor of Rome's mission to rule, as we see in the beautiful line from Anchises' prophecy to Aeneas (*Aeneid*, VI, 852):

Tú regeré imperiú populós, Románe, meménto.

In his poem is embedded an epitome of all Roman culture, even as that of the later Middle Ages is found in the Divine Comedy of Dante, who regarded him as his master and model. Augustus' own *Res gestae*, the summary of his stewardship, promulgated at his death by Tiberius and inscribed on plates of bronze set up before his mausoleum and copied elsewhere, may still be read in the two imperial languages, Latin and Greek, on the walls of the ruined temple of *Rome and Augustus* in far-off Ankara (An-cyra) in Asia Minor—now the capital of the Turkish Republic. These "memoirs" give us a picture of Augustus the statesman, while his proclamations and say-

ings give us a picture of Augustus the man. They furnish us the outline around which the whole story of his policy and reign can be written.

In old age Augustus, ever frail and now worn out with his attempt of nearly a half century to found a stable government, and cast down by public worries—conspiracies against his life and especially Varus' defeat in Germany, and by domestic griefs—the deaths of many relatives and the erring career of his only daughter, Julia, a "princess" in licentiousness—resolved to take a holiday by accompanying Tiberius part way on his journey to Illyricum, sailing along the Tyrrhenian coast to Capri and going inland as far as Beneventum. On returning through Campania he fell ill at Nola, where he had been born nearly seventy-seven years before. Suetonius tells us that in his hour of death, after Tiberius had been recalled and Livia and friends had reached his bedside from Rome, he called for a mirror and, after having his hair combed and his shrunken cheeks adjusted, asked "whether he seemed to have played the farce of life well,"¹ adding two lines from a Greek play:

If all be right, with joy your voices raise
In loud applause to the actor's praise—

words which symbolized his character and policy. Then, left alone with Livia, he admonished her "to live mindful of our union" and expired on August 29, A.D. 14, on the anniversary of his first consulship in 43 B.C., the first great Roman to die peacefully in his bed since Lucullus, the conqueror of Mithradates, seventy years before. Then over his body brought to Rome Tiberius and his son Drusus delivered addresses, and it was burned in the *Campus Martius*, when an imprisoned eagle was released and flew into the sky, a symbol that Augustus was now with the gods, and Livia laid his ashes in his tomb.

¹ *Ecquid videretur mimum vitae commode transigisse*, Suetonius, "Augustus," 99.

We, like his deathbed friends, must say he had well played "the farce of life," for it is hard to find in history a career longer or more full of trouble than his, begun fifty-eight years before when, a youth of eighteen, he had come to Rome to plunge into the turmoil caused by his uncle's murder, and now peacefully ended in the midst of the *Pax romana*. For over forty years, the longest reign in Roman history, he, to quote Professor Pelham, "had successfully played the difficult part of ruling without appearing to rule, of being at once the autocratic master of the civilized world and the first citizen of a free commonwealth. He had instituted a new world epoch and determined the course of empire for centuries; he had gained the affections of provincials and Italians, had pleased the commons and conciliated the nobles."

His work will always be differently judged as well as his character. Tacitus (*Annales*, I, 8-10) says that both friendly and hostile opinions were expressed at his death, just as the assassination of Julius Caesar fifty-eight years before "was regarded by some as a deed of unexampled atrocity, by others as an achievement of superlative glory." But all recent writers on his life from Dumeril and Gardthausen in the late nineties of the last century to Dessau and Holmes in the twenties of this—and some four new biographies appeared only last year—agree that his glory is that he founded a new state out of the fragments of the old, that which Caesar failed to do, a timely régime which kept Rome from centrifugal destruction and gave her time to work out her mission; and, above all, that he instituted the longest peace in history. None need, therefore, any longer follow the judgment of Voltaire that he was merely the destroyer of the Republic and of political liberty in the ancient world.

Our estimates must vary according as we consider the dubious means by which he obtained power, or the legal use of that power when won. It is only since Mommsen and his collaborators collected the inscriptional evidence and reduced Roman constitutional law to a science that we can discard much of the gossip of Suetonius and even of Tacitus, alone available to Merivale and his contemporaries, and so reach a reasonable verdict, by contrasting the ruthless cruelty of the triumvir with the mild rule of the emperor. He had begun his public life with one purpose—to avenge his uncle's death, and in exacting that revenge had been guilty of cruelty and readiness to sacrifice friend or foe alike. The proscriptions of 43 B.C. are among the worst crimes of history, and his failure to save his friend Cicero the worst blot on his name. And here Augustus must shoulder a part of the blame, and entire responsibility for the destruction of Perusia. In palliation, if there be room for a gentler judgment, we may urge his youth and the long duel with rivals and allies who were older, without pity and intriguing to destroy him. In the course of that struggle he came to see that his great goal was not revenge, but mastery of the Roman state. To attain this he used every art, but when the struggle was over his real nature came forth, for he devoted the blameless remainder of his life to the reconstruction of the state and the happiness of his people. Then intrigue, deceit and cruelty were laid aside, and he became the true statesman, willing to rule only with justice and legally with the senate. It is from that period that the benevolent and placid features of his great portrait-statue from Prima Porta look down upon us. And it is for this that his name will always be found among the great ones of history—the unique *Imperator Caesar Augustus*.

SCIENCE AND SOCIETY

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THE title of this address is comprehensive enough to cover the whole gamut of human experience since that day in the distant past when the first primitive man stood upright and realized that he was different from other animals. The word "science," in its broadest sense, might be taken to include all knowledge, while "society" is certainly descriptive of the long succession of communities that have come into existence since the dawn of time.

Since I do not wish to range so far afield, and cannot aspire to the historical erudition that has made such a task possible for Professor Arnold Toynbee, I shall begin by specifically defining the scope of this analysis. By the term "science," I mean only those new discoveries from experiment and observation that have steadily enlarged man's accurate knowledge of himself and his environment, excluding for the time being writings that are purely intuitive or depend solely upon the imagination of the author. As to "society," I shall use that term to include the communities of western Europe and North America—the area of what has been called "western civilization"—and to exclude all others. This use of the word does not imply any superiority inherent in the members of western society; it simply emphasizes the fact that the other societies at present existing in the world have developed along rather different lines, and that mankind cannot be treated as a single unit for the purpose of this analysis. Finally, as to period, I wish to confine my remarks to the four centuries between 1475 and 1875, with some brief discussion of the subsequent years by way of epilogue.

Defined in this fashion, the problem is still a large one, but it has a definite significance. During this period, western civilization was revolutionized. At the beginning, we find the crystalline organization of medieval society, compact and conservative: at the end, the world had been knit together by developments in transportation and industry, while society showed signs of flying apart and was far from conservative. To what extent was this change due to the impact of science?

THE PARADOX

Any survey of the answers that have been offered to this question, and they are legion, reveals a distinct cleavage of opinion. The apologists of science are filled with such joy that their words are a continual paean of praise: science has made all things new. Science has created a better world than any that existed before: mankind should "rejoice and be glad therein." But the critics are equally vehement. They suggest that the progress of scientific discovery, and its implementation by enterprising business men, has destroyed the old social values and disorganized society. They look not to the psalms for their slogan but to "Pilgrim's Progress" and, with one of the most sensitive among men, cry aloud, "What shall I do to be saved?"

Such a confusion of witness cannot lightly be dismissed. No honest man can seriously suggest that the controversy is simply a battle between truth and falsehood, unless he is convinced by some inner light (which science cannot record) that his own interpretation is the true one, and that all those who disagree with him are numbered among the Sons

of Belial. For most of us, there is something to be said on both sides of the argument. Defenders of scientific discovery can point to the tangible results that science has produced, but how will they answer a man like Lord Stamp (whose mind is certainly as brilliant as that of the scientists he reproaches) when he pleads for a moratorium on inventions?

We are confronted by a paradox at the outset of our inquiry, and can only proceed if we recognize that the defenders and the critics of science are both accurate, in the light of their basic assumptions. But we must go further than that. It is apparent that the impact of science on western society, during the period under review, has not been a simple one. Omelettes are not made without breaking eggs, and it may clarify our thinking if we separate the constructive effects of science from those that have been purely destructive.

THE CONSTRUCTIVE IMPACT OF SCIENCE

In a congregation of scientists and scholars, there is no need for me to describe in detail the magnificent achievements of scientific discovery. The steady growth of human knowledge has made it possible for scientists and technicians to work miracles with the natural resources that surround us, revolutionizing the material fabric of society by their activities. A few summaries must suffice to indicate the full impact of science in this respect.

If we take the broad group of the physical sciences, which include engineering as their handmaiden, we are amazed at the results that have been achieved. In regard to industrial production, men have harnessed the powers of nature to the wheels of complicated and precise machines in such a way that the burden of human labor has been greatly reduced. Men can produce the commodities that they have always used with a fractional

part of the effort that was required two hundred years ago, and can also produce a galaxy of new articles that contribute to the comfort of life. Allied with these developments in the industrial field are the equally significant strides that have been made in transportation and communication. As many a political orator pointed out during those halcyon days of the nineteenth century, when men believed fervently in free trade, each of us is apt to find on his dinner table products that have been brought, cheaply and expeditiously, from every corner of the earth. We can travel with such comfort and celerity that it is easier to get from Montreal to Melbourne to-day than it was for Charlemagne to go from Paris to Rome, while the invention of the radio and telephone enables us to exchange views with every part of the world without leaving the comfortable armchair in which we sit. The magic carpet that appears so often in the stories of the Arabian Nights was less marvelous than some of the gifts that science has offered to every man—and, even in the fantasy of those stories, there were but few individuals who owned magic carpets or had the power to command jhinns!

When we turn to the medical and biological sciences, the same tale of successive miracles must be told. The average life of men and women has been steadily increased, as a result of diminished infantile mortality, better sanitation and the steady progress of medicine and surgery. The span of man's years during the middle ages had fallen far below the "three score years and ten" that were deemed reasonable during the epoch of the Cyriac civilization, but the progress of science has more than recovered the lost ground. Moreover, although I speak subject to the correction of the neurologists and psychiatrists who sometimes cast doubt on the assertion, the average man and woman to-day enjoys

continuously better health as well as longer life.

Turning to still another group of sciences, the one that includes geology, agriculture and chemistry, we are confronted with a record of steady increase in the number and variety of the products that are made available to us on the market. Agriculture has enlarged the selection of foods that we can eat, while chemistry has made it possible to preserve those foods so that they will be available at all seasons. Agriculture and geology have revealed new raw materials for industry: chemistry has transformed them into a thousand articles that minister to human comfort and enjoyment. Queen Elizabeth was delighted to accept, as a unique luxury, the first pair of silk stockings, but those stockings would now be regarded as uncomfortable atrocities by the girl who can purchase for a few cents an infinitely more attractive pair made of nylon or celanese.

I shall not prolong the catalogue, since it is familiar to you from the enthusiasm of many panegyrics. Modern industry and big business, in order to evade the issue raised by the critics of scientific progress, have used all the resources that they command to advertise the fact that the material comforts now available to the average man are greater than those that could be obtained by Charlemagne or William of Normandy in the days of their greatest power. There is no need to prove the existence of something that is apparent to every observer who is familiar with the history of the recent centuries.

THE DESTRUCTIVE FORM OF SCIENCE

But what about the other side of the picture? What arguments can the critics find that will have weight enough to influence our judgment when there is so great an accumulation of material evidence to attest the benefits of science?

It has been well said that "man shall

not live by bread alone." Society is not a number of individuals, each leading a separate existence, nor is it a mob drawn together by the excitement of the moment and composed of people who have nothing in common except their reaction to that excitement. Society is an organism which we can envisage as endowed with a kind of independent life that enables it to continue in existence despite the procession of births and deaths that determines the lives of the men and women who compose it.

I do not want to push this vitalistic concept too far, and am using it rather for illustration than for argument. The significant fact, which must be emphasized, is that men cannot live together in a society unless there is a dominant philosophy or ethos that they share in common. The ideals towards which society is directing its efforts, and the standards by which the conduct of its members will be judged, must be comprehended (however dimly) by each member of the group. When that common philosophy is lost or there is dispute as to the aims of the community the society comes to an end.

This fact is significant. A criminal gang, such as that ruled by Al Capone in Chicago a few years ago, may constitute a society. As long as its aims and standards of conduct were recognized by all its members, it was able to withstand the pressure of governmental action and public opinion, but it collapsed rapidly when these conditions no longer existed. The story of the Roman Republic could be told in the same terms, as could that of any of the great civilizations known to history, since common ideals and a recognized standard of conduct are the binding forces that unite men into a single society much more effectively than that economic interdependence which has been discussed *ad nauseam* during the last hundred years.

Scientific discovery, *per se*, does not

have any direct effect upon the ethos of society, since science is concerned solely with facts and methods rather than with the ethical implications of those facts. But we must remember that the average man is neither a scientist nor a philosopher. His concept of the aims and moral standards of the society in which he lives are apt to be the result of vague traditions and dogmatic inculcation, rather than of any clear thinking on his own part, and this concept may be seriously damaged by the discoveries of science.

Here we are dealing with something much less tangible than the physical impact of scientific knowledge upon those material resources of the world that constitute the environment of society. We are concerned with a climate of opinion, in which the social consciousness of scientific progress is in conflict with the old ideals and traditions, and it is important to realize that the true impact of science is not in this respect to be measured by accurate knowledge of the results of laboratory experiments but by the general public's concept of the nature of the discoveries. The average man listens to gossip and reads the newspaper: he does not study scientific journals. His concept of scientific discoveries would often horrify the trained scientist, since the average man seldom troubles to remember all the limiting conditions within which a particular statement holds true. The discovery of U-235 is not to him the partial verification of an interesting hypothesis: it is the creation of a new fuel that will drive the *Queen Mary* several times around the world if a couple of pounds of it is placed in a tub of water. Yet, inaccurate and dangerous as they may seem to us, we must concern ourselves with these popular concepts of scientific progress if we wish to understand that destructive impact of science on society which has aroused so many critics during recent years.

MAN'S CHANGING CONCEPT OF HIMSELF

Even though we may not share the sentimental enthusiasm of Cobbett or Hilaire Belloc for the society that existed in the middle ages, we realize that medieval social philosophy was utterly different from anything that has followed it. Man was at the center of the universe. God had brought him into existence as the crowning act of all creation, on a world that had been made specially for his benefit. The sun was created to light him by day, and the moon and stars performed the same office by night, as all the heavenly bodies rolled steadily around the earth in their appointed spheres. Moreover, the Son of God had come down to earth and offered himself in a unique and awful sacrifice, in order to redeem man from his sins and offer him the hope of eternal blessedness.

And what of man, what was his duty in this vast creation? The question could be answered in one phrase: "To love righteousness and do justice." Under the guidance of the church, man was required to live this life so that he might qualify for salvation in the next, and that injunction was two-fold. Although the first commandment ordained that he should love God and worship Him, the injunction that man should love his neighbor as himself was just as specific. Even though the actual situation may have fallen far short of the ideal, the whole structure of feudalism (and of the early guilds in towns that broke away from feudal control) emphasized the fact that each man was his brother's keeper. Society was an organism, a poor reflection on this earth of the perfect celestial society above, and each individual had his appointed place. His rights and his responsibilities were both clearly defined, and the standards of justice were quick to condemn any evasion of responsibility. Just prices and just profits, the duty of a master to his servant, and all

the injunctions of Thomas Aquinas, must be set against the writings of Adam Smith if we would truly appreciate the extent of the contrast between medieval society and our own.

This contrast is, I think, due more to scientific discovery than to industrial and commercial developments (since the latter are not incompatible with a medieval philosophy), and there have been three great stages in the process of evolution. In each case, the change in the ethos of western society occurred slowly, as the realization of scientific discovery seeped into social consciousness and became, almost unconsciously, a factor influencing the prevailing climate of opinion.

The first impact came with the Copernican revolution in the field of astronomy, which can conveniently be dated by the publication of "*De Revolutionibus Orbium Celestium*" in 1543. Scientifically, it might be suggested that it made little difference to human happiness whether the sun moved around the earth or the earth around the sun, yet the tortured story of Giordano Bruno's vacillation during his trial shows the extent of that contrast in terms of contemporary philosophy. Copernicus and Galileo shattered the medieval cosmogony. The earth was no longer the center of the universe: it was a blob of mud whirling around a flaming orb and, throughout the infinity of space, the stars were other suns that might well be surrounded by other planets. There might be hundreds of other worlds, each peopled by men, so that God must have repeated the act of creation many times, and the Son of Man offered himself anew for the redemption of each planet. The idea was unthinkable, yet could not be dismissed. Medieval society had rested so firmly on its belief that this earth was the center of the universe, and humankind the chosen people of God, that the new science was devastating in its effect. During the agonies of the Reformation serious men

attempted to reshape both religion and philosophy, while others sought relief in the agnosticism of the new learning, but neither were able to pour the new wine into the old bottles and preserve the vintage.

The discoveries of Newton, and the birth of modern physics, struck another blow at the old philosophy by entirely removing God from the universe. It was not the angels who guided the planets, but the force of gravity. The universe was not a miracle that operated only because of the watchfulness and loving care exercised by God the Father: it was a machine that responded to the laws of physics.

Nothing would have saddened Isaac Newton more than this bald statement which, as a godly man, he would have denied with all the force that he could command. But the average man of the seventeenth century did not read the "*Principia*" any more than his descendants study the scientific publications of Einstein. The mechanistic philosophy (which underlay the emasculated deism of a Chesterfield) was the result of the impact of Newtonian physics on the prevailing social consciousness, and the older conception of a divine order of society vanished. Even the serious religious leaders made no effort to restate social philosophy in its broadest sense, but attempted rather to emphasize the doctrine of redemption and the loving-kindness of God toward the prodigal that ultimately returned. It is hard to find anything brave or constructive in the activities of Isaac Watts during the years when he lived in sylvan luxury at Abney Park!

Both of these blows had been purely destructive: they shattered the fabric of the old society without offering any new philosophy of constructive purpose to replace the warmth of the imagery that they destroyed. But biology came to the rescue during the nineteenth century.

Darwin's "Origin of Species" appeared to offer final proof of the theories that Lamarck and others had formulated a generation before, and the gospel of evolution became a significant part of the climate of opinion.

I say "gospel," because the idea that gripped the public mind was vague and evangelistic. It possessed none of the scientific caution and precise formulation for which Darwin himself was famous. The doctrine of the survival of the fittest created in the public mind the certainty that anarchy was safe and desirable. The struggle of tooth and claw was considered to be as appropriate in the field of industry, as it was assumed to have been in regard to the natural selection of living species in a jungle existence. The greater the struggle, the more certain it was that only the fittest would survive. Failure served to demonstrate the unfitness of the individual in question, and anybody who should be so anti-social as to offer charitable aid to his weaker brethren was only retarding the inevitable progress of western society.

Once again, it must be remembered that the realities of daily life did not—fortunately for many of us—carry out the full rigors of the contemporary philosophy. Men are creatures of emotion and habit. They did not adopt in all their relations the ruthlessness of nineteenth-century philosophy any more than their ancestors had created in perfection on this earth the ideal society described by the Canonists. But our grandfathers did believe in the gospel of progress with all the fervor that was in them. The mere fact of success demonstrated the fitness to succeed, and since success made more noise than failure, it was obvious that society was moving steadily forward.

THE NATURE OF THE SOCIAL SCIENCES

The social sciences have not, as yet, been mentioned in this account of the

impact of scientific discoveries upon the ethos of western society. The omission is deliberate. Despite the excellent work of the Encyclopaedists in France and the multitude of pamphlets on economics and politics which appeared in other countries, the prevailing climate of opinion was scarcely influenced by social and economic considerations until the beginning of the nineteenth century. The social sciences were born at a moment when the impact of natural science had already sorely damaged the ethos of western society; at a moment when mankind was vigorously entering upon a competitive struggle for the accumulation of natural wealth.

Within a single generation, however, the social sciences were characterized by an internal controversy that is peculiarly their own and has been used by critics to taunt their disciples ever since. Adam Smith, who was a moral philosopher rather than a specialized economist, had outlined, in "The Wealth of Nations," an optimistic philosophy of individualism and progress that might fittingly be regarded as the hypothesis that foreshadowed Darwin's work in the biological field. But Sismondi, who looked at war-torn Europe after Waterloo, found conditions very different from those that Smith had observed in eighteenth-century England, and challenged the whole gospel of laissez-faire.

This internal controversy, which still persists, arises out of the subject-matter with which the social sciences deal. They are concerned with human beings, with individuals of different training and wide varieties of emotional response. Conscious experimentation is not open to the social scientist who wishes to test his hypotheses, and since macroscopic observation is not always easy (because the social scientist does not live any longer than the men who he is studying; nor is he endowed with any greater powers of observation) he sometimes develops a

tendency to introspection. By analyzing his own response to a given stimulus he tries to judge how other men would respond.

Such an attitude is far from scientific, and critics who like to generalize have suggested that there are no such things as social sciences. They have condemned the whole business out of hand, and insisted that there can be no science without experiment. Nothing could be further from the truth. The paleontologist, without the aid of experiments, has made important contributions to the fund of human knowledge, and the meteorologist has solved many scientific problems, although he has no control over the phenomena he studies. Astronomy is among the oldest of the sciences, and seismology is to-day accorded scientific status, yet controlled experiment is impossible in both of these fields. The fundamental features of any science are useful hypothesis, accurate observation of data and utter devotion to truth, and I know of no reason that prevents the study of men and of society in scientific fashion.

The task that confronts the social scientist is not, however, an easy one. As we look backward at what has already been done, we realize that it is not the difficulty of observation that has limited the usefulness of the social sciences, but the pressure of custom and tradition. Since the political scientist has human prejudices, it is hard for him to forget his instinctive veneration of the British Crown (or the Constitution of the United States) when he sets out to study the efficiency of government. The problems with which the social scientist has to deal arise directly out of an environment that is so ingrained a part of his own habits of life that it is hard for him to get far enough away from it to formulate constructive hypotheses for study. Over and over again, we have seen that an individual from a totally different

community will offer the best explanations of particular conditions in our own, and provide solutions that had not occurred to men already steeped in the traditional environment of the problem in question.

SOCIAL SCIENCE AS RELIGION

As a result of these difficulties, the social sciences have developed along two divergent lines, and the exponents of the two methods of approach are getting further and further apart.

The first group of writings consists of a steadily growing pile of monographs that deal with specific problems, and it must at once be admitted that many of these are of first-class quality. As examples, one might cite the work that has been done in the field of industrial organization, the financial studies of borrowing corporations that are daily undertaken by the research staffs of our larger banks, and (on a wider canvas) the studies of population and national income that have appeared during the past five years. Even the best of these studies have had little or no effect on the ethos of western society, since they are concerned with narrow problems of method, or with aspects of economic activity which (despite their importance) directly affect the conscious lives of very few individuals, while the worst of them are scarcely useful for the specialist. As a matter of fact, some of the specialized studies in this latter group appear to have been undertaken, not because the investigation seemed of fundamental importance to the scientist but because there was a plenitude of data available, so that elaborate statistical techniques could be applied with little trouble. Indeed, there is reason to think that availability of data in handy form has done much to inspire hundreds of the monographs that now accumulate dust on our library shelves, and it would require more mental courage than I pos-

ness to suggest that society would be any better off if all of them were brought from their resting place and studied carefully by other social scientists. The man who complains that the reading public is not interested in his work should first ask himself whether he has, in fact, discovered anything that is of real concern to society.

The significance of this remark is apparent if we study the fate of the second group of writings in the broad field of social science—the writings that are frankly evangelical. Although Marx was an avid (and in some ways brilliant) student of history, his theory of the rise of the proletariat and his analysis of the causes of business crises do not arise directly out of his historical investigation. Yet it must be admitted that, for every man who to-day reads Marx in order to study his specific contributions to economics and history, there are thousands who believe fervently in his gospel of the proletarian revolution. Even if Marx was wrong, he was writing about a problem of deep significance to many men, and he was imbued with a serious realization of his mission. I know of few more interesting things in the history of economic thought than those passages in the correspondence of Marx and Engels, written during the panic of 1847, when those two serious economists were learning to ride, and busily studying military strategy, in order that they might lead the masses when the final revolution occurred.

The case of Adolph Hitler is even more pronounced. You can read "*Mein Kampf*" from end to end without finding any evidence of economic, sociological or historical research, and nothing that we know about the author suggests that he is devoted to scientific habits of truth in reporting, and perseverance in investigation. The volume is frankly evangelistic. It attempts to show men the way to what Hitler regards as salvation, and,

unfortunately, millions of its readers have become converted to the gospel.

This type of literature, much of which is now classed under the heading of social science, is not scientific at all. Karl Marx and Adolph Hitler, St. Simon and Robert Owen, all these are evangelists or philosophers (call them what you will) who are attempting to offer to society a new religion and a new ethos. They recognize that the march of scientific progress has destroyed the old philosophy, with its clear aims and fixed standards of judgment; they recognize, too, that the philosophy of laissez-faire and inevitable progress which dominated the nineteenth century is not rich enough to satisfy mankind or comprehensive enough to serve as the effective bond for western society. In place of the worship of God and the elevation of man, which inspired medieval society, they would place the revolution of the proletariat or the deification of the state.

THE PRESENT PROBLEM

The evangelists of autarchy and communism are not alone in their realization that all is not well with the ethos of western society. Thoughtful men, in all countries, have grown less sure of the slogans that their fathers shouted so exultantly, and it has become amply apparent that mankind has not yet learned to use its new-found wealth with wisdom. The pains of the business depression that we suffered yesterday and the horrors of war that we endure to-day suggest that we have not yet created a perfect society.

But no thoughtful man will be inclined to accept, as a gospel of salvation, the Nazi version of a policy that Diocletian adopted as a last desperate resort in the hour when the Roman Empire was crumbling. Progress does not lie in the direction of a retreat that would compel us to abandon most of the things that mankind has striven through long centuries to attain, and we do not wish to

solve our problems by crystallizing society on a low level of material well-being. To-day we recognize more clearly than ever before that our ideals are more precious than our goods and, by the very recognition of that important fact, we perceive the dichotomy of our problem. Each aspect of it demands separate consideration.

In the first place, we must define clearly the philosophy of our society. What are the ideals that it cherishes? By what standards will it judge its members? This is not a scientific problem, and it is not capable of solution by scientific methods. It concerns economics no more than it concerns physics, since science merely shows what will happen if we do a certain thing and remains silent as to the wisdom of the act.

But this problem is of direct significance to every one of us as members of western society, since the life of our society depends upon the fact that we do share common ideals and that these ideals are strong enough to hold society together during both prosperity and adversity. Moreover, we must bring to our study of this problem (even though it be labeled religion or philosophy) the same love of truth and the same desire to investigate that characterize our work in the narrower scientific fields. All too often, we have seen the scientist become a man of prejudice as soon as he leaves the laboratory, so that his attitude before the ballot box shows none of the patience and judgment that appear in his professional writings.

It should also be emphasized that our decision on this problem of social philosophy must be as specific as the decision on any scientific question. All of us, in this hour of our nation's crisis, believe so fervently in the ideals of democracy and liberty that we are willing to sacrifice ourselves and all our goods for their defence. But have we clearly defined those ideals? What is our attitude to-

ward the conflict between national sovereignty and an organized world? How do we define "the ideals of democracy" in regard to such things as freedom of trade, social insurance and migrations of people? How can we ensure the welfare of society and yet preserve the freedom of the individual? At the present moment there is no clear answer to these questions from western society as a whole, yet this broad problem of social philosophy must be solved before we can expect that the impact of science will become wholly beneficial. We must know what we want to do before we can expect our tools to be of use.

The second problem, which becomes more important as soon as the answer to the first has been clearly given, is that of adopting means to ends. Even though our social scientists have no responsibility, as scientists, for the socialization of ideals, it is reasonable to expect that they will show us how to attain those ideals once they have been clearly stated. A clear solution of the philosophical problem defined above will naturally point the way toward the formulation of more fruitful hypotheses in the field of economics and political science, so that we may expect an integration between the two divergent types of work that we have noticed in the broad field of the social sciences. Specialized monographs might be expected to deal with more fundamental problems while comprehensive studies would naturally be expected to be established more directly on the foundation revealed by specialized studies. Moreover, investigations of the kind that are contemplated here would naturally involve on the part of the social scientist considerable knowledge of the things that are being done in the fields of the physical and natural sciences. We need an integration not only between comprehensive writings and specialized monographs but a further integration that brings into focus the significant

results that have been attained by scientists working in other fields.

The adaptation of means to ends; the charting for society of a course that is most appropriate in the light of the existing fund of human knowledge, is the primary function of the social sciences. It will not be an easy task, but its importance should call forth the finest efforts of every individual. Moreover, the work that has been done during the past few years is sufficient to indicate that social science can offer splendid contributions. The analyses of national income and capital formation made by Dr. Kuznets, in the United States, and the comprehensive study of the financial system that is now being made by the National Bureau of Economic Research, provide just the kind of information that we shall need for the rehabilitation of society when this war is over. Even more important, these studies have developed a method appropriate to the macroscopic investigation of economic

and social phenomena, and have shown the way in which further studies can be made that are of more direct significance to Canada and to the world.

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Looking backwards, therefore, it is apparent that the impact of science on society has not been wholly beneficial. The ethos of western society has not responded to the changes in its material environment, so that to-day we face a major crisis. Even though everyone of us confidently expects that the democratic powers will, in the long run, attain a military victory in the present struggle, that victory will not solve the problems that confront us. Western society is as much endangered by the slow process of crystallization as it is by military assault. But if we are willing to face the major problem of deciding upon our ideals, the forces that science has placed at our disposal are already sufficient to make the attainment of those ideals a practical possibility.

FLAGS AND BOUNDARY LINES

For an organization like the Rockefeller foundation which over many years has tried to carry on its work regardless of flags or boundary lines, these are unhappy days. To sit by and watch the disappearance or decadence or, worse, the perversion of institutions of learning which in earlier and better years we were privileged to assist is not an easy assignment. In the decade that followed the war these institutions gave high promise in public health, in medicine and in the natural and social sciences. The Institute of Hygiene at Warsaw, the Institute of Public Health at Prague, the Kaiser Wilhelm Gesellschaft in Berlin, the Institute of Psychiatry at Munich, the Institute of Inorganic Chemistry at Göttingen—these were a few of many organizations, in a world where thought was free, to which the foundation gave needed assistance.

Even more difficult is it to see the brilliant men with whose work we were associated—many of them on fellowships or with grants in aid from the foundation—now driven from the posts for which they were trained, debarred from their laboratories, some of them fugitives, some in concentration camps, many of them separated from their families or lost in foreign

countries where they sought haven. To these scholars scattered in many lands, whose lives are now a sacrificial testimony to the principle of intellectual freedom, we in this protected hemisphere pay tribute of admiration and homage.

The development of the war has had the further effect of driving back several of the foundation's outposts established in connection with its own operating program around the world. Our Paris office has been closed and the Shanghai office transferred to Manila. A temporary office has been opened in Lisbon. Our personnel has had to be recalled from Egypt, where work was being carried on in malaria and schistosomiasis; from Turkey, where we were engaged in sanitary engineering; from Rumania, where scarlet fever studies were being conducted; and from Hungary, which was a station for influenza research. However, foundation personnel is still operating on the Burma Road, in India, in South China, in the Belgian Congo, in Uganda (Central Africa), in Spain and Portugal and of course in Latin America.—*The Rockefeller Foundation Report for 1940.*

THE HAPPY ACCIDENT

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PROBABLY the most fascinating of all natural phenomena is that of creation—from the unknowable genesis of this terrestrial sphere itself clear on down to the emergence of some pat idea for a new tenpenny toy. What mysterious and diverse ganglia must fall magnetically into alignment, what vague and explorative star-groping must precede the sudden and spontaneous episode of the birth of an idea, like a rain-drop globulating in a fog under the benign influence of some vagrant channel of chilled air?

In a letter to Dr. Caspar Wistar in 1807, Thomas Jefferson refers to "the slow hand of accident" transferring mysteries to the table of sober fact, as though a majority of the advances in science made up to that time had come by some such vicarious route. Probably the prevailing conception of scientific discovery is most popularly exemplified by Charles Goodyear's "accidental" discovery of the vulcanization of rubber. Every one knows and can visualize the picture of Goodyear puttering around in his humble kitchen with his fuming mixtures and clumsily upsetting his pan of india rubber and sulfur; the ensuing sputtering on the hot lid of the stove, and, lo, the great scientific discovery!

It is common to human nature to embrace such a happy accident. Who would not desire also to stumble upon some such chance fame and fortune? The drama appeals to every basic mentality. It is ever the short cut, the easy way, the avoidance of good hard honest sustained labor that is always so enthusiastically welcomed by the mass mind.

The radio, popular literature, the loose parley of the streets, all exalt such

moments in the course of human progress as Goodyear's "lucky" and chance discovery. Not so prevalent, however, is the emphasis on all the substantial progress, all the hours of dull, minute and precise scientific prying that eventually crystallized in that sparkling moment of the spilled mixture. These are overlooked and disregarded as inconsequential, having no bearing upon the ultimate result. Yet the simple facts are that for ten long years prior to his moment of success, Goodyear had almost ceaselessly attempted to find a method by which rubber could be made to withstand the extremes of heat and cold. In 1837, two years before his happy accident, he had worked with a man who had made some experiments with rubber mixed with sulphur, and he had bought the right to use this unperfected process. The lucky accident could neither have happened to, nor the significance of it been appreciated by, any one without the prepared mind which Goodyear already had. Once again, as Pasteur had suggested, luck favored the man who was best prepared to make use of it.

It is not the lay mind alone, however, that is inclined to overemphasize the apparently easy or soft part of the scientific procedure to the disparagement of the long preparatory road that must be laid up to the mountain top before the scene can be unfolded. Direct criticism has come in recent years from higher circles of thought. Charges are levelled at science, citing its "pebble-picking" and its inability to digest satisfactorily the data already assembled. We have been told that there is a revulsion against science for these and other sufficiently

obvious reasons. This revulsion of course is not a new or isolated phenomenon. Partially it derives no doubt from the perversion of scientific progress in the utility of warfare; again, from the apparent slowness of science's advance in certain of the deepest human needs.

It has been implied that if more effort were made toward the extraction of general principles out of already known facts, perhaps for a time at the expense of the labor incident to collecting new facts, progress would be expedited and the factual material already on hand made more useful to society. To this proposal to put more emphasis on intellectual activity than is being done, and less upon the tools, one may agree in theory, in so far as it proves practical. However, the reaction of those who are impatient of recorded progress only too often expresses itself simply in the form of such proposals to modify or ignore the prevailing methods. That it is not feasible to suppose that the course of science can be charted on a schedule like a train, wilfully and intentionally, is clearly indicated by the observable data of its history.

But first, before science as such can be properly attacked, it must be defined; its boundaries and outlines must be made familiar. Sarton said that "Science is nothing but the human mirror of nature." That is a very satisfactory beginning, but it should be added that science, in dealing with the phenomena of nature, is characterized especially by its attention to their interrelationships.

That I am pessimistic about the outcome of attempts to expedite the progress of science or of the general applicability of its discoveries, by tampering with the method, will appear at once from my definition, for I propose to define the scientific method simply as that method which, as a result of centuries of experience, has been found to give the best results in the search for truth in the

field of the unknown. The method consists of a mixture of intellectual activity and technique or tools. The proportions vary within wide limits, but the method is incomplete without either of its ingredients.

Many volumes have been written on the philosophical and metaphysical implications of science. Since I am taking a rather pragmatic view of science and of its place in human affairs, we may omit most of the philosophical background. We must, however, I believe, say that there is no such thing as absolute knowledge or absolute certainty, and that the quest for ultimate causes is not our concern. Science operates within a framework which for practical purposes is tacitly assumed to be fixed. We have recently had, thanks to Mr. Einstein, an illustration of what happens when the framework itself is shaken or destroyed. We have seen that science itself does not collapse. It merely becomes necessary to rebuild within the new framework.

Systematic scientific knowledge is founded upon certain theories, postulates or concepts which by almost universal consent are regarded as true, even though they are incapable of direct proof, as long as they serve to support the vast structure which is built upon them. For example, there is the theory of evolution; also the belief that there is such a thing as reality in the material sense, and the doctrine of cause and effect. Science does not depend upon these specific beliefs or postulates, but it should be clear that science rests upon these and other postulates so long as they prove useful in arranging our knowledge—and no longer. The overturning of any of these postulates would mean a rearrangement of knowledge but not a destruction of science—since by definition "science is nothing but the human mirror of nature."

It thus becomes clear that science deals

not with facts, in the absolute sense of the word, but with the most probable explanations of observable phenomena. While it is a common practice to speak of scientific facts, it should be understood that a statement of so-called fact represents the truth only if a whole series of fundamental postulates are true. Recognition of the most probable as the ultimate attainable by science and the scientific method has led to the wide use of statistical methods, and the treatment of data from the standpoint of the theory of probability.

How, then, does the scientific method actually work; what are the procedures followed by a scientist in his daily life? From an analysis of the actual practice of the profession of a scientist perhaps we may come nearer to an understanding of the methods he uses.

First of all, let it be understood and accepted that the pursuit of scientific work, as with all creative endeavor, is first and foremost an art. There is an art of observation, an art of experimentation and an art of applying the intellectual process to the material with which the scientist works. There is something of a paradox in the statement that the scientist must be an artist, but nevertheless this is true; and to recognize this is of extreme importance. As Fagin said, "The true artist is the perpetual explorer. He cannot invent the substance of his work, but he can discover it in the life of nature and his fellow-men." So also with the scientist.

The pursuit of truth is highly individualistic, for in addition to each scientist, each field of work and each particular problem has its own individuality. All kinds of men with all kinds of equipment from the standpoint of intellect, knowledge and technique are engaged in scientific pursuits.

Sir Francis Bacon, who lived from 1561 to 1626, is generally credited with having given the first impulse to the

creation of the scientific discipline as we know it to-day. The method which he formulated was to consist first in the collection of facts into a sort of natural history, and second in the drawing of conclusions from these facts by the logical process of induction, or reasoning from the particular to the general. He appears to have believed that the collection of all the necessary facts would occupy only a relatively short time, and that once in possession of the full supply of facts, mankind could work out all of its problems by reasoning alone.

Although it has been amply demonstrated that science has *not* progressed in the manner laid down by him, and although it is almost universally agreed by scientists that the Baconian method, taken by itself, is unworkable, there are still proposals, particularly in the newer fields of knowledge, to return to his method. Bacon omitted three of the most important features of science as we know it—the working hypothesis, experiment and deduction, or reasoning from the general to the particular.

To-day the scientific method which the scientist, adequately trained, equipped intellectually and technically, proceeds to apply, over-simplified, consists of the formulation of a working hypothesis, the planning and carrying out of observations, and/or experiments to test his hypothesis; revision of the working hypothesis as many times as may be necessary, and the formulation of a conclusion, which may or may not confirm the original hypothesis. From the conclusion, which, in the theory of logic, is arrived at by induction, other conclusions may be arrived at by the process of deduction. Thus when Einstein, on the basis of certain facts or theories, formulated a conclusion in the form of the theory of relativity, he predicted that rays of light passing from the stars near the sun must deviate from a straight path, if the theory were to hold true as a

generalization. The verification of such predictions is an important part of the scientific method.

Even from this over-simplification it is obvious that the scientific method is far from simple. It requires powers of reasoning as well as of observation and/or experiment; and it requires not only that these powers work together toward a common end, which is the search for the truth, but also that they do so without interfering with each other.

In actual practice the difficulties are even greater. We start with the formulation of a working hypothesis or a preconceived idea. Random collection of facts without a working hypothesis hardly deserves to be called science. The working hypothesis is supposedly formulated on the basis of all the facts known to the observer. The scientist now attempts to predict what will happen under a new set of conditions. Often he is content to say that one of a number of things will happen, and to leave the answer entirely to nature. But rarely does he do an experiment just to see what will happen, without any preconceived ideas.

He does an experiment and repeats it enough to eliminate experimental error. His working hypothesis must now be accepted, rejected or modified; or if he has a number of alternatives the number is reduced, and new experiments are devised to enable him to arrive at the correct hypothesis. He then examines his data for other possible explanations of the phenomena observed, devises new experiments to avoid ambiguities and finally arrives at a conclusion.

Now this immediately affords us an opportunity of indicating the position in science of the process of reasoning as compared with observation and experiment. The experience of every scientist, good or bad, is that the preconceived idea or working hypothesis—without which there is no science, but only dabbling—is

a most unreliable affair, and that there is no substitute for submitting the idea to the criterion of the scientific method *in toto*, which includes observation or experimentation for verification. The true scientist has learned from his own experience that it is never safe to take one single step forward into the abyss of the unknown by the intellectual processes alone.

Perhaps this might be answered by the observation that scientists are not sufficiently trained in the process of logic; but it is clear that this difficulty, which is common to all scientists, is not due to a defect in the process of reasoning. Just as a mathematical problem can be solved only on the basis of the variables that are stated, just so can a scientific problem be solved only if all the relevant facts are included in the statement of the problem which led to the formulation of the working hypothesis. And it is precisely in the inclusion of all relevant material that the difficulty lies, for as soon as unknown territory is entered no one can predict what will be relevant and what irrelevant. Here genius lies in the ability to foresee the relevant and to ignore the irrelevant. It is apparent, therefore, that the powers of reasoning, taken by themselves, are incapable of leading to anything more than working hypotheses, whenever the field of the unknown is entered, and that the only safe scientific attitude is one of doubt with reference to unverified working hypotheses.

This applies with particular force to phenomena in which the variables are numerous and uncontrollable. We have abundant illustration of the truth of this in our abrupt attempts to modify the economic and social situation of the present. A great many individuals, among them many competent and well-informed economists, are attempting to predict what will happen as the result of certain administrative procedures. Their theories and predictions are in

fact working hypotheses, and when the President puts their recommendations into effect he is simply carrying out the next step in the scientific method—that of verification or rejection.

Similarly, the scientist must at all times be ready to drop his working hypothesis or to modify it to fit his observations. A great difficulty arises here in the all too human tendency to attempt to make the facts fit the preconceived idea. This is one of the hardest obstacles to overcome in any scientific work. An unexpected result is obtained or a wholly new phenomenon observed. The first impulse with nearly all investigators is to discard the unexpected as being due to experimental error, and thereby to close the mind to it, even though it is well known that out of such unforeseen observations may come the most brilliant discoveries. The scientist must consciously and deliberately train himself not to disregard observations which do not fit in with his preconceived ideas. The combination of "chance and the prepared mind" is still the best combination known for real discovery.

Quite properly there is importance in rational analysis, which may mean mathematical or logical treatment of facts, in contrast with empiricism, or the mere recording of observed facts. While I would be the last to deny the value of mathematical or logical treatment of factual material, I share the belief with many others that the processes of conscious formal logic have in the past had too high a value put upon them as tools of discovery. This is precisely for the reason that induction and deduction, in the formal sense, are useful only in so far as they can be applied to relationships already known to exist; whereas the essence of science is the discovery of new and unpostulated relationships.

Rational analysis is first and foremost the method of establishing or rejecting suspected relationships and of bring-

ing order into observed and related facts. Without such analysis science ceases to be science. Rational analysis is also often of great value in postulating, and even in predicting, the nature of the unknown. Thus, from the behavior of the remainder of the solar system the existence of another planet in the system was postulated before Neptune was discovered, and the search for this planet was given direction. Also, when Mendelejeff discovered the systematic relationships among the atomic weights of the elements and formulated the Periodic Law, he was able, in 1871, to assert the existence of three new elements, so far unknown to the chemist, and to assign them definite properties. His prophecy was completely vindicated within the next fifteen years by the discovery of gallium in 1871, scandium in 1879 and germanium in 1886. Also, in several instances he questioned the correctness of accepted atomic weights on the ground that they did not correspond with the Periodic Law, and his judgment was vindicated by subsequent investigation. Such predictions—and the list is long—were the result of rational analysis. But in no instance did the rational analysis constitute the actual discovery.

That actual discovery may come through rational analysis alone is, however, not impossible. But it occurs only if the data or factual material at hand include all the relevant variables, as the result of a happy accident. If the relevant material is all at hand as the result of foresight, then another mental process begins, which Claude Bernard describes as follows:

Apropos of a given observation, no rules can be given for bringing to birth in the brain a correct and fertile idea that may be a sort of intuitive anticipation of successful research. The idea once set forth, we can only explain how to submit it to the definite precepts and precise rules of logic from which no experimenter may depart; but its appearance is wholly spontaneous, and its nature is wholly individual.

A particular feeling, a *quid proprium* constitutes the originality, the inventiveness or the genius of each man. A new idea appears as a new or unexpected relation which the mind perceives among things. All intellects doubtless resemble each other, and in all men similar ideas may arise in the presence of certain simple relations between things, which every one can grasp. But like the senses, intellects do not all have the same power or the same acuteness; and subtle and delicate relations exist which can be felt, grasped and unveiled only by minds more perceptive, better endowed or placed in intellectual surroundings which predispose them favorably.

I believe that Claude Bernard is correct in his statement that "no rules can be given for bringing to birth in the brain a correct and fertile idea." However, in the light of modern psychology we can perhaps arrive at a better understanding of how such ideas do get born. It is my belief that the perception of a new or unexpected relation occurs almost always first in the unconscious. The scientific worker supplies the material to the unconscious by his conscious mental activity, time elapses, something clicks, and out comes the idea, fully born. It is not by any means always correct, but it is always suggestive. To the degree that the unconscious produces such ideas, and that they are correct and far-reaching, is the owner of the unconscious fortunately endowed for a scientific career. The genius is the man whose unconscious is exceedingly productive of "correct and fertile" ideas, and whose conscious mind is prepared to receive and act upon this product. Needless to say, this ability can not be inculcated by any system of education or training; it can only be given the opportunity to develop in a propitious environment.

I use the term unconscious to distinguish mental processes of which we are not conscious from those of which we are, and am chiefly concerned with its intellectual rather than its emotional attributes. These functions of the unconscious were described fully by von Hartmann in his book, "The Philosophy

of the Unconscious," first published in 1868. That this function of the unconscious appears to have been lost sight of at the present time may possibly be due to the much greater emphasis put in recent years upon the role of the unconscious in the emotional life.

Accidental discovery comes most often to the man who has given much conscious thought to the problem upon which he is engaged and who is in a position to grasp, through both conscious and unconscious mental processes, the significance of any accidental observations he may make. Thus accidental discovery is most apt to come to the scientist who makes the greatest use of his faculties, including those of rational analysis. It is, of course, also clear that accidental observations occur only when the scientist is actively at work.

Futhermore, it is equally clear that the unconscious, even though it has a peculiar faculty of perceiving hitherto unsuspected relationships, can also deal only with that material which has been put into it. The unconscious must therefore be fed not only with factual material but also with relationships carried as far as rational analysis can go. Consequently, other things being equal, the better supplied the unconscious is with factual material and with the products of rational thinking, the more likely it is to produce new relationships. Contrarily, the unconscious can produce nothing out of a vacuum, and great discoveries are very unlikely to come from minds of poorly informed individuals, with inferior intellectual capacities. The superior quality of the unconscious is thus due not to any mystical properties, but solely to its ability to deal with a larger number of simultaneous variables than can be dealt with by the conscious processes of logical and mathematical analysis.

The peculiar position of the unconscious can perhaps be illustrated best by

an example of the type of thing it does. Most scientists carry in their minds a vast body of apparently unrelated material. A scientist may be engaged simultaneously on several aspects of the same problem. He analyzes his material in terms of known relationships, and often makes conscious systematic attempts to discover new relationships. In addition to his attempts at rational systematic thought, which in any case is more theoretical than real, and in addition to his mathematical treatment of his data, his conscious mind is busily engaged during most of his waking hours with the details and the general significance of his problem. He may make a new and perhaps accidental observation, or he may read in the literature of observations made by others. A new train of thought is started, which goes on—half consciously and half unconsciously. Finally, and perhaps more often than not, when he is not consciously thinking of the subject at all, the observation, seen in its proper relationship, often uniting other previously apparently unrelated phenomena, comes into his conscious mind as a flash of inspiration. There follows then much work to test and verify the validity of this new relationship; but the discovery itself has already been made.

This is the ordinary process by which a scientist proceeds. Brilliant and far-reaching discoveries have been attributed largely to accident or to genius. Yet both genius and accident require a background of knowledge, of work with facts, observation or experiments, and of preparation of the mind.

The same process applies to all creative work. Sir Arthur Quiller-Couch, in speaking of the art of writing, declared: "Let me assure you that in writing solid daily practice is the prescription; these crests only rise on the back of constant labour. Only out of long preparation can come the truly triumphant flash."

Napoleon, whose career was filled with "luck," believed this was equally true in the field of the military. He said that battles were won by the sudden flashing of an idea through the brain of a commander at a certain critical instant. The capacity for generating this sudden spark was military genius. Napoleon consciously counted upon it, always believing that when the critical moment arrived the wild carnival of confusion of the battlefield would be illuminated for him by that burst of sudden flame. But if Napoleon's mind had not been stacked with military facts, statistics, logistics and the theories of the past, if he had been ignorant of all the prosaic business of his profession instead of attending to it more closely than any other commander, would those moments of supreme clearness have availed him, or would they have come to him at all? Clearly he was ceaselessly storing away in his subconscious mind the silage upon which he was to feed in the great moment.

How many apples had fallen upon the earth before the one that germinated the law of gravitation in the mind of Newton? How many men had seen a lantern swing before Galileo's brain was so stimulated to create his most epoch-making astronomical discovery?

Roentgen was dabbling with some evacuated tubes as scientific toys when some fluorescent material which happened to be in the neighborhood of his tube glowed. Unwittingly he had discovered the x-ray. Proof that electrons are of the nature of waves resulted from the accidental breaking of a container of liquid air in the laboratory of Davisson and Germer. Raman was studying the scattering of light from benzene, toluene, etc., when on the photographic plates which he used, he discovered wholly unexpected lines, which were the result of the breaking of quanta, the bundles of energy that make up light. Galvani came upon knowledge of the muscle nerves and their reactions to electricity

through the accidental touching by his wife with a metal scalpel a frog upon a machine for generating frictional electricity. The stethoscope evolved out of a French boy's recollection of tapping messages to playmates at the opposite end of felled logs.

One day in Paris in 1875 a young man in a laboratory cut his finger and applied some collodion to the wound. The pain in the finger kept the young man awake at night, and he lay pondering over a problem that was continually in his mind: namely, how to find a suitable means of combining guncotton and nitroglycerin. He hit upon the idea that this might possibly be done more successfully with nitrocellulose which was only slightly nitrated than with such a substance as the collodion which he had just used. He went down to his laboratory at four o'clock in the morning and when his assistant arrived he showed him the first specimen of blasting gelatin which he had produced in a flat glass vessel. It consisted of nitroglycerin with the addition of a small proportion of a solution of nitrocellulose in ether.

Now in the equation cut finger + collodion + X = blasting jelly, who but Alfred Nobel could have served for Mr. X? His entire life, and the lives of all his family, had been devoted to experiments in explosives. His father before him was an inventor who had served the Russian government in the work of developing submarine mines. A precocious and brilliant student, Nobel was a terrific and a tireless worker, with more than one hundred patents to his credit. From blasting jelly he went on to smokeless powder and other inventions. Could the cut finger and collodion have resulted similiary for any one else? Not likely.

In trying for a \$10,000 prize offered for a synthetic substitute for ivory for billiard balls, John Wesley Hyatt treated cotton cellulose with nitric acid and thereby obtained a substance which he

called celluloid. Before that, however, Hyatt, who was a printer, was interested in developing a printers' roller material, and had patented a device for sharpening knives. Later he developed the famous Hyatt roller bearing.

In 1890 Dr. Adolph Spitteler, of Hamburg, was trying to make a white blackboard for use in his classroom. Whimsically he mixed sour milk with formaldehyde. The result was a shiny, horn-like substance—casein.

Dr. Leo Baekeland, of Yonkers, N. Y., in 1908, was trying to create a fusible, soluble material to substitute for the expensive natural resins, when by putting his mixture under high heat and high pressure he obtained instead an insoluble and infusible material now known as Bakelite, the first synthetic resin, created out of carbolic acid and formaldehyde. Baekeland had some 400 patents to his credit. He had created Velox paper and was a professor of chemistry before he was 24 years of age. He worked specifically on his problem for four solid years before his "happy accident."

There were recorded cases of gastric fistula before that of Alexis St. Martin, the Canadian *voyageur* of Mackinac Island, but it remained for Dr. William Beaumont to recognize opportunity in this historic accident and so become the pioneer of knowledge of the gastric juice and the processes of digestion.

In virtually all these and many other similar accidental discoveries, the event was not so much the accident itself as the understanding and interpretation of it by the alert scientist present on the job.

In the field of science, stepping aside from genius in its highest form, we find that most capable investigators approach problems in the systematic manner called the "analytical method" of research. In essence the method consists in taking a phenomenon apart to see how it works

and then putting it together again. It is a very important method, and one that should not be decried, for most of the solid advances in knowledge come, directly or indirectly, from the application of this method—either before or after the birth of an original idea. Certainly no one could have been more systematic than Darwin, who spent a lifetime in collecting observations out of which the theory of evolution emerged.

However, the systematic method alone is not apt to yield brilliant results, for the reason that it is usually impossible to isolate any phenomenon and to study every one of its factors. The systematic method, however, does orient the scientist in his problem, provides him with facts which may be arranged in orderly fashion by conscious mental effort, and so supplies the material which can be made use of by the unconscious.

In so far as there is disagreement between scientists themselves as to the relative value of the components of the scientific method, I suspect that the quarrel is between two different temperaments. One suspects the other of wishing to avoid hard work by the methods of "arm-chair science," while the other's fear is that too high a value will be put upon hard work as an end in itself. In point of fact there is no substitute for either the intellectual processes or for the hard work that goes into the making of observations and into experimenting. The immediate result of new hypotheses created by intellectual activity is, as we have seen, always the necessity of more hard work. The difference between the two schools is therefore more theoretical than real.

I pass over the "pebble-picking," or blind accumulation of unrelated facts, for in the extreme form implied by these words this hardly deserves consideration, though in actual practice there is often difficulty in drawing the line between pebble-picking and the purposeful accumulation of needed data.

It is the goal of every science, and of every real scientist, to arrive at such generalizations as are suggested, and in a minor way they are constantly being derived from existing knowledge. But generalization is more difficult than the proposal to expedite it by concentration would imply. The process of generalization requires not only study of the facts at hand, but also a key. The key may come from new observations, or from a new method, and with the key at hand the task of generalization becomes easy. But more often the key to generalization, as in the case of the individual problem, comes from the unconscious mind, and the observation that known facts fit the new generalization better than any previous hypothesis, and that new facts can be predicted from it, provide the support for the generalization. Now the finding of such generalizations is even more a mark of genius than is the case in the individual problem, and the fact that the really great generalizers can almost be counted on the fingers, including Galileo, Newton, Darwin, Pasteur, Mendel, Faraday, Einstein, should be sufficient to indicate the extraordinary difficulty of the process. And in each case the new generalization has resulted in the necessity for more rather than for less actual labor.

Certainly a worker whose own intellectual processes have not led him above the routine collection of facts can not be made into a generalizer by insisting that he devote some time to thought. Except in so far as a better understanding as to how the scientific method actually works may lead to improvement in our educational processes, it seems to me that science can do no more than to continue to progress by the combination of intellectual processes and good hard work, which makes up the scientific method as we understand it at present.

It is typical always of the inert theorists to prefer the happy accident, as such,

and to be impatient of the long drudgery of preparation and production. To them, the long "spring training" of the baseball pitcher would seem simply a waste of time. The ace should spring full-blown from the brow of Zeus onto the hillock and there proceed to improvise his form and technique for mowing down the opposition. It might be a more enjoyable world, to be sure, if all this were possible and likely; but human experience demonstrates conclusively that it is not.

To the professional theorists the crystallization need not require the heat

and the bubbling cauldron. Columbus should simply have sat on a rock and imagined the outlines of the New World. Why bother with a boat? By chance, perhaps, Luckhardt came upon the sleeping carnations from the greenhouse; but it was a long, arduous and always dangerous progress from that happy accident to the invaluable discovery of the utility of ethylene as an anesthesia.

Who can say that there would still be these moments of crystallization without the innumerable, infinitesimal and infinite pressures? There is no basis for suspecting it.

THE ANNUAL NUMBER OF ECLIPSES

By WILLIAM and BERTRAM DONN

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THE following discussion is a more complete explanation of the annual number of eclipses than is generally met with, although the treatment omits those factors whose bearing on the results can be considered negligible. For the purpose of an orderly explanation, many fundamental concepts are introduced first.

The maximum annual number of eclipses is 7, five solar and two lunar, or four solar and three lunar, and the minimum is 2, both of the sun. Solar eclipses occur only at new moon, when the moon's shadow falls on the earth's surface; lunar eclipses occur at full moon, when the moon crosses the earth's shadow in the course of its orbital motion.

The plane of the earth's orbit is known as the plane of the ecliptic. Since the

moon's orbit is inclined to this plane at an angle of five degrees, eclipses can only occur when the full or new moon is at or near the nodes (the two points at which the moon's orbit crosses the plane of the ecliptic). However, the moon need not be situated exactly at the node to cause an eclipse. As is shown in Figs. 1 and 2, the maximum distance from the node, measured along the ecliptic, at which the earth's shadow (or the sun from the opposite node) can be, for an eclipse of the moon is the lunar eclipse limit. The greatest distance the sun can be from the node at time of new moon, and cause an eclipse of the sun is the solar eclipse limit.

There is a range in the eclipse limits since the radii of the orbits of the earth and moon vary with their respective

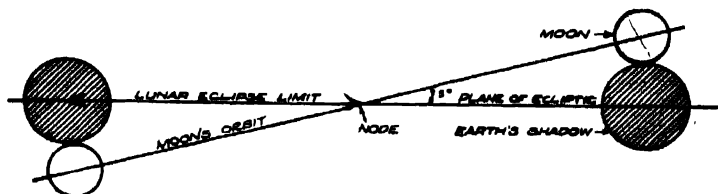


FIG. 1. MAXIMUM DISTANCE EARTH'S SHADOW CAN BE FROM NODE

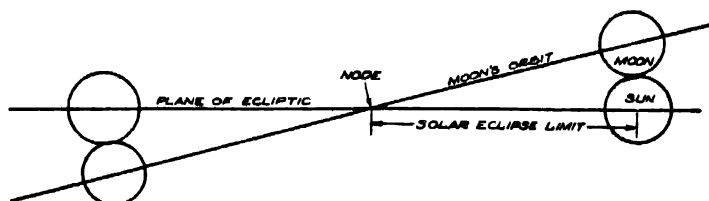


FIG. 2. MAXIMUM DISTANCE AT WHICH SUN CAN BE FROM NODE

positions, causing a variation in the angular dimensions of the sun and moon. The major solar limits are $18^{\circ} 31'$, and the minor, $15^{\circ} 21'$. For the moon the range is from $12^{\circ} 15'$ to $9^{\circ} 30'$. It is noticed that the solar limits are about fifty per cent. greater than the lunar limits. This can be seen from Fig. 3, where the diameters of the cone of light, whose elements are tangent to the sun and earth, into which the moon must move to cause eclipses, plus the moon's diameter, are in the ratio of 3 to 2.

Whenever the sun crosses one of the nodes of the moon's orbit, it will be within the eclipse limits and an eclipse season occurs. It is clear that this must happen twice a year. Further, since the moon's nodes make a complete regression in a little over 19 years, the sun crosses the same node a little earlier each year, the period from node to node being 346.62 days. This period is the eclipse year. Should the sun cross the node early enough so that the first eclipse season falls in January, then two eclipse seasons and part of a third season will occur in a calendar year, since the eclipse year is shorter than the latter.

The minimum solar eclipse limits are

$15^{\circ} 21'$. Twice that interval is greater than the sun's motion in a synodic month, as the sun moves through the sky at a degree a day. The synodic month is the time between two successive occurrences of the phase of the moon, and is $29\frac{1}{2}$ days. Therefore in an eclipse season the sun cannot pass through the limits under a synodic month and avoid a new moon in the region of the nodes. Consequently, the sun must be eclipsed at least once during each season, yielding a minimum of two solar eclipses annually.

If a solar eclipse occurs early enough in the eclipse season, the moon will overtake the sun again, still within the eclipse limits, causing a second solar eclipse in the one season. From this it can be seen that the moon must be full half way between the two solar eclipse positions, resulting in a lunar eclipse in the same season. An additional fact becomes evident. Since the two solar eclipses in this situation must occur at the extremities of the eclipse limits, they will always be partial eclipses, whereas the full moon between them will be at or very close to the node and hence will always be totally eclipsed.

As the major lunar limit is $12^{\circ} 15'$,

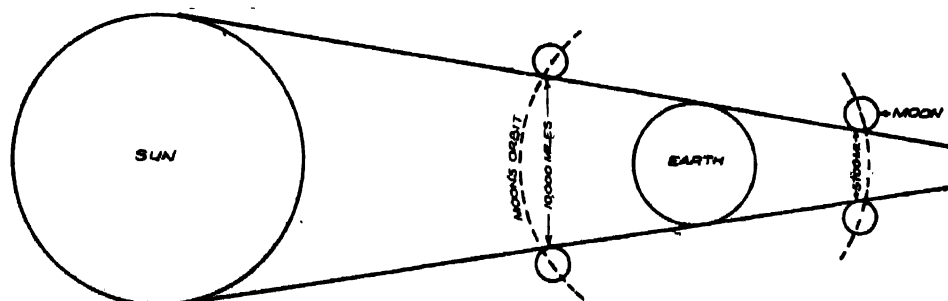


FIG. 3. CONE OF LIGHT INTO WHICH MOON MOVES TO CAUSE ECLIPSES

twice that is less than a synodic month. Thus the sun can move through the limits without once encountering a full moon. As a result a lunar eclipse need not take place at any eclipse season of the year.

For the five: two eclipse ratio to exist, three eclipses must occur in each of the first two seasons, and one solar eclipse in the third season of the same calendar year (or the reverse of this arrangement). If the sun is eclipsed 17 days and the moon 2 days before the sun passes a node, then the sun will again be eclipsed 12 days after that node, and in the second eclipse season of that year a solar eclipse will occur 13 days before the node, and lunar and solar eclipses will occur 1 and 16 days respectively after the node is passed. Since 12 synodic months are equal to 354 days, it is readily seen that the sun will be eclipsed for the last time nine days before the node of the third season, yielding seven eclipses in all. These time intervals may only vary by a couple of days, and still allow three eclipses in each of two successive seasons.

To show that 8 eclipses are not possible in a calendar year we may consider the following situation: the sun is eclipsed as early as January 1st. Then from the conditions given the third node is passed 363 days later (17 plus 346, the eclipse year). This leaves two days to the end of the year. Consequently, the full moon previous to this is before the lunar season, while the full moon after, although it is eclipsed, is in the next calendar year. Therefore eight eclipses may occur in three successive seasons, but only seven can occur as a maximum in a year.

To obtain the four: three ratio, the eclipse seasons must merely occur a bit earlier, so that the first solar eclipse which we considered on Jan. 1st, falls in the previous year, and the lunar eclipse which was missed at the end of the year, falls in the present year, giving three lunar and four solar eclipses.

With the five: two ratio, the sequence of eclipse dates as a whole has a range of 11 days, resulting from the 11 days between the last eclipse and the end of the year. In the second case the intervals as previously defined may vary by approximately 5 days since the first solar eclipse need no longer exist to get seven, in addition to the 11-day range of the sequence as a whole.

Before concluding we may examine actual examples of the cases which have been developed.

1935—the five: two ratio

Jan. 5—Partial eclipse of sun
Jan. 19—Total eclipse of moon
Feb. 3—Partial eclipse of sun

June 30—Partial eclipse of sun
July 16—Total eclipse of moon
July 30—Partial eclipse of sun

Dec. 25—Annular eclipse of sun

1917—four: three ratio

Jan. 8—Total eclipse of moon
Jan. 23—Partial eclipse of sun

June 19—Partial eclipse of sun
July 5—Total eclipse of moon
July 19—Partial eclipse of sun

Dec. 14—Annular eclipse of sun
Dec. 28—Total eclipse of moon

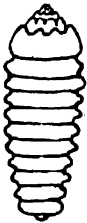
LEAF-MINING INSECTS

By Dr. SIBYL A. HAUSMAN

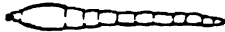
DEPARTMENT OF ZOOLOGY, CONNECTICUT COLLEGE

"There's never a leaf nor a blade too mean to be some happy creature's palace."—Lowell.

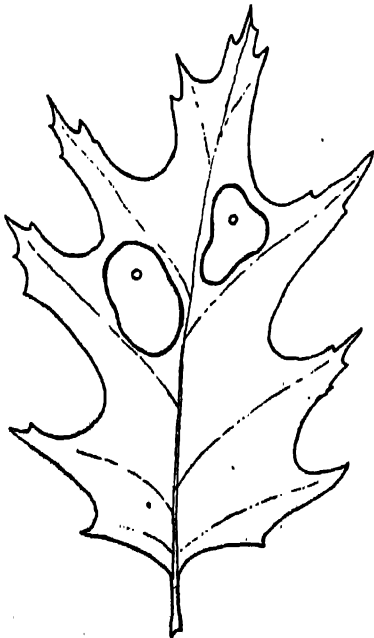
Among the most interesting of the plant-feeding insects are the so-called "leaf-miners." They are rarely seen, except by entomologists and ecologists who set out to look for them, because they



dorsal aspect



lateral aspect



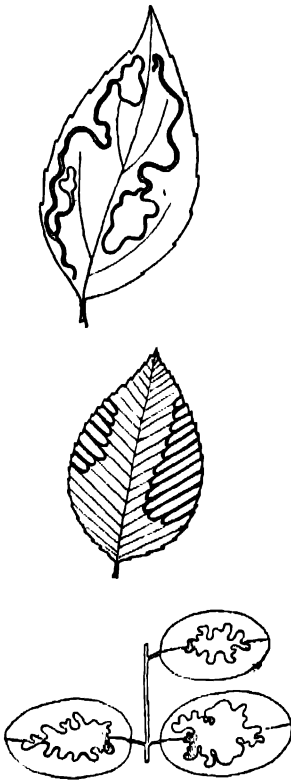
RED OAK LEAF-MINER AND ITS WORK
ABOVE: DORSAL AND LATERAL ASPECT OF THE
LARVA. BELOW: MINE OF RED OAK MINER.

are very small and inconspicuous. These tiny creatures are small worms, the larval stages of insects which are able to obtain plenty of food and a suitable lodging by living entirely between the upper and lower surface cells of leaves.

Certain members of the *Lepidoptera*, *Coleoptera*, *Hymenoptera* and *Diptera* insect orders spend their larval life within the leaf tissues, feeding on either the palisade or spongy parenchyma cells where the chlorophyll is located, well protected and concealed by the thin, colorless cells of the upper and lower epidermis.

The larvae usually enter leaves through the under surface and eat their way along into the green cells, leaving behind them various patterns which appear as transparent mines in a green leaf. These mines are fairly obvious to the casual observer and may be well known as pests to greenhouse workers and vegetable growers when they affect a large percentage of the foliage. The forms of these mines or tunnels, and the leaves of the kind of plant where they occur, are both characteristic of a given species. Often the mines are obscured by the accumulation of dark particles of waste material, known as frass, but some species keep their mines clean by distributing the frass in separate pockets. This habit is also characteristic of the kind of miner.

Mines in leaves offer considerable variety in styles. Some of them are straight or linear, snake-like or serpentine, blotch, linear blotch, trumpet and digitate. Mines may also be classified as to the depths to which the miners penetrate. A full mine is one in which the larva eats out both palisade and spongy



THREE MINE PATTERNS

ABOVE: SERPENTINE MINE. CENTER: WORK OF SCOTCH ELM LEAF-MINER. BELOW: MINE OF LOCUST LEAF-MINER.

parenchyma cells. Others mine only in the palisade layer, as, for example, the black locust leaf-miner.

Ecologically, the miners themselves may be grouped into two types, the *Diptera*, or flies, and the others, certain beetles, sawflies, wasps and moth and butterfly larvae. The *Diptera* larvae are cylindrical and tapering, with mouth parts adapted for tearing away and rupturing the cells. Others are streamlined and flattened dorsoventrally, with wedge-shaped heads and mandibles in front which work like shearing organs. Other adaptations are the absence of legs and spines and the reduction of eyes and antennae.

One of the best known of the leaf-

miners can almost always be found in the leaves of the common locust tree. This is the work of the digitate Lepidopterous leaf-miner, *Parcetopa robiniella*. This mine typically extends along the mid-rib and spreads out on either side. The frass is packed away in one end, leaving the rest of the mine clean. When fully grown, the miner leaves the mine and spins a cocoon in a fold of a leaf or in a crevice in the bark. By holding a mine up toward the light, the frass and tiny larva can be observed inside, or they can be seen by gently tearing off the loose, thin epidermal cells.

In leaves of the well-known jewel weed, or "touch-me-not," which grows in moist woodlands, is often found the serpentine mine of a dipterous leaf-miner, *Agromyza borealis*. This mine is linear, winding and thread-like, ending in a large blotch. Dark specks of frass form a line down the center.

Of the coleopterous miners, one of the easiest to find is the work of the red oak miner, *Brachys ovata*. This is a rather conspicuous brownish mine on an interspace of the leaf. When the mine is old, or in pressed specimens, a flat, scale-like egg is visible on the surface, as a shiny, round speck. The larva passes the winter in the mine in fallen leaves, the pupa being formed in late May. The adult beetle emerges in about seven days.

One of the *Hymenoptera*, a sawfly, is of particular importance economically because of the injury to leaves of the Scotch elm. In some localities, the damage done is so severe that every leaf is dry and brown and the tree has the appearance of being dead. These larvae often mine out the leaves completely between the veins, working during the months of May and June. Injury to the trees is completed by the end of June when the larvae leave their mines and winter over in cocoons in the soil. They pass through six instars, finally becoming flattened, pure white worms with a brown

head capsule vertical to the plane of the body. Pupation occurs in late April after the transformation of the larvae.

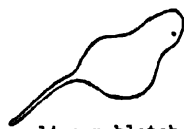
Many of the miners are of economic importance because of the damage done to shade and ornamental trees or to plants the leaves of which are used for food. Mining not only weakens the foliage, and hence the entire plant, but also serves as points where disease and decay may start. Leaves of vegetables are made unsalable and unattractive by the mined-out areas. Leaf-miners on marketable crops such as spinach, beets and Swiss chard are hard to control because they are so well protected. Spraying with nicotine sulfate, "Black Leaf 40," has met with partial success.

The leaf-mining larvae are truly fascinating to examine under a binocular microscope. Their remarkable adaptations in form and structure to the narrow limits of their environment, together with the types of these environments, which they fashion by means of highly adapted mouth parts, are extremely interesting.

Life histories of these insects offer attractive problems for ecologists and field biologists, and can be studied by placing the miners with their leaves in easily constructed containers. Such rearing



linear



linear blotch



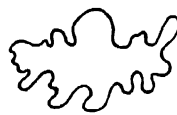
serpentine



trumpet



blotch



digitate

TYPICAL MINES

chambers can be made by cutting a hole in the center of a cover of a small, tight carton and fitting the open end of a glass vial in the opening. A rim of cotton may be placed between the opening and the vial to serve as a wedge and to provide for air.

The mines within the leaves can be kept indefinitely by pressing and covering with Cellophane.

WRITTEN RECORDS OF FOREST SUCCESSION¹

By ELIZABETH CHAVANNES

UNIVERSITY OF WISCONSIN

OCCASIONALLY the ecologist is able to augment his ideas of plant succession with evidence taken from sources which are less fashionable than the quadrat and fossil pollen. Such an opportunity is found in the written records left by man where one may read a part of the story of the encroachment of forest upon the prairies of southern Wisconsin.

In place names, surveyors' maps and notes, and in such documents as letters, journals, and military reports, the nature of the landscape has been described in greater or lesser detail for more than a hundred and fifty years. The recency of these records of change in the prairie-woods balance in the southern part of Wisconsin does not detract from their value. Rather it enhances them as a sort of postscript to evidence of plant migrations in post-glacial time.

All plants were forced to retreat before the last advance of glacial ice which extended into Ohio, Indiana, Illinois, Wisconsin and Iowa. A narrow belt of tundra and conifers thrived at the edge of the glacier; but in the warm, fairly dry climate they gave way rapidly to xerophytic prairie plants on the south and west, and to mesophytic woods on the east.

As the glacier receded, the plants followed in its wake. At the same time that an arid post-glacial climate hindered formation of an extensive coniferous belt and slowed the advance of the deciduous forest, it helped the prairie establish itself. This latter movement culminated in the so-called "prairie peninsula" formed across Illinois, Indiana, southern

Wisconsin and Michigan, and Ohio, its eastern limits now marked by relic colonies.

The first advance of the mesophytic forest and retreat of the prairie was begun in later post-glacial times after a climatic change, apparently in the direction of increased rainfall with winter as well as summer rains. The forest continued its westward advance from the Ice Age stronghold in the Appalachians until it extended to and perhaps beyond the Mississippi River and developed considerably in both area and density.

Once again the balance was thrown in favor of the prairie, and in those states of the "prairie peninsula" there occurred a second advance which developed certain characteristic elements of the prairie and woods floras. Prairies stretched over the moraines and outwash plains, and along river bluffs and ridges in the Driftless Area, that unglaciated portion of southwestern Wisconsin extending also into the adjoining states.

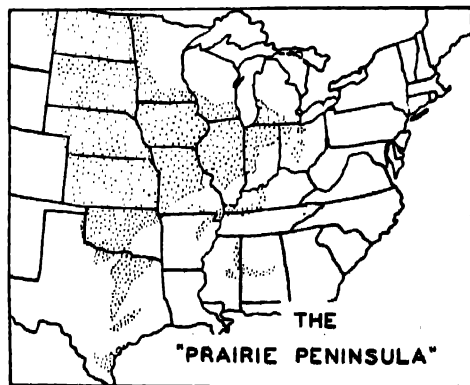


FIG. 1. EASTERN EXTENSION OF THE PRAIRIE.
SINCE THE RETREAT OF GLACIAL ICE. (MODIFIED
AFTER TRANSEAU, AND FENNEMAN.)

¹ The greater part of this work was done while on a grant from the Wisconsin Alumni Research Foundation during the summer of 1938.

The prairies were spotted by isolated trees, or by scattered groves. Lakes and main water courses were fringed with woods of oak, hickory, basswood and maple, rich toward the east, thin in the west and south. A part of the wooded country lay in oak openings where spreading open-grown trees were underlain by prairie, rather than by forest litter.

In such a condition of mixed floral elements the woods could not advance as a single unit. Depending on whether the invading plants spread out from a prairie grove or into and through a relic colony isolated in the woods, the movement was centrifugal or centripetal. Despite strong tendencies toward en-

croachment, a balance slightly in favor of the prairie seems to have been maintained in most of southern Wisconsin until the nineteenth century when the culture of the white man was introduced.

Of the written records man has left, the three aforementioned classes all suggest that a substantial invasion of prairie area by woods has occurred within the limits of historical time. The significance of place names lies in the fact that when the pioneers migrated into a vast strange country they often turned to nature for their names. That the Indian had earlier done the same thing is shown in the name "Muscodia, place destitute of trees."

Prairie names stretch across the state

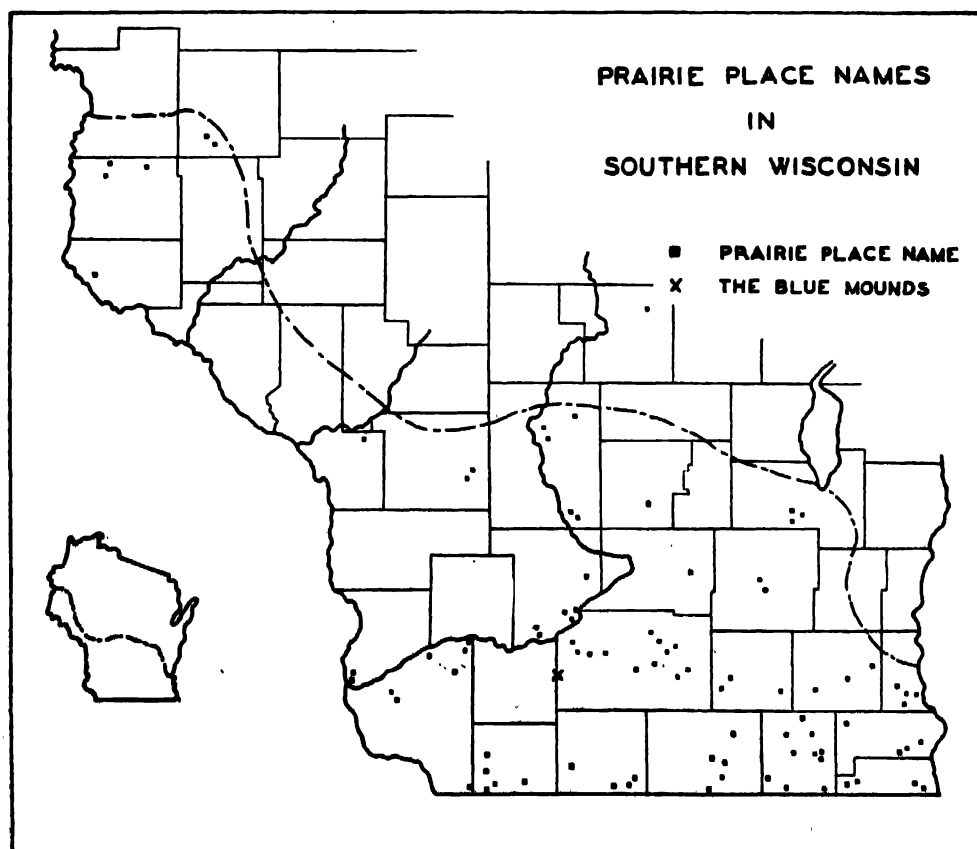


FIG. 2. DISTRIBUTION OF PRAIRIE PLACE NAMES IN SOUTHERN WISCONSIN
 DOTTED LINE INDICATES HYPOTHETICAL BOUNDARY BELOW WHICH LAY NEARLY ALL WISCONSIN'S
 PRAIRIE AT THE TIME THE STATE WAS SETTLED.

from Lake Michigan to the Mississippi River: Pleasant Prairie, La Prairie, Sun Prairie, Prairie du Sac, Star Prairie. Post office names are supplemented by an abundance of colloquial names which persist locally, such as Bigfoot Prairie, Gardner's Prairie, Caldwell's Prairie. Not only was the fact of prairie recorded, but often size and shape, as in Heart Prairie and Twenty-Mile Prairie.

The town of Burr Oak suggests the presence of isolated trees in tracts of prairie. Other indicators of prairie are scattered groves, surprisingly abundant judging from the many names: Oak, Emerald, Union, Patch, Allen's and Gratiot's Groves, and a host of others. Such names as Deer Park perpetuate the oak opening, a type of tree-dotted prairie, characteristic of wooded areas and commonly described by a reference to English park scenery.

Names of a Richwood, Glenwood, Woodland type appear frequently, as do several Forest townships in the north and east. Scrub vegetation characteristic of areas undergoing encroachment is described in Hazel Green, a village name referring not to a pioneer's sweetheart, but to a condition commonly found in burned-over woodland. After ground cover and trees were destroyed by recurrent prairie fires, hazel brush sprang up thickly, persisting through the fires by virtue of a sturdy root system, flourishing as a scrub between destructions.

Out of this welter of names comes the realization that below a line running diagonally across the state from the southeast lake-shore corner, northwest to the counties beyond the end of the Mississippi River lay nearly all the prairie Wisconsin possessed at the incidence of historical record.

This general picture can be made a great deal more specific by the notes written as the area was surveyed, and by the maps prepared from the notes. It was the custom for the surveyors to walk the section lines, which run at one

mile intervals, and to record the types of vegetation through which they passed, as well as the number and size of noteworthy trees. Thus the vegetation of a vast amount of country was systematically charted, for the most part by competent sober men.

Corollaries of the notes are the maps based upon them. As nearly as one can tell, they were drawn directly from the notes, frequently not by the surveyors themselves and usually not for some years after the actual survey. They delimit woods and prairie in such a fashion that the result corroborates the distribution which place names indicate. Reports of copses, thickets and scrubs of hazel and oak confirm the presence of an encroachment hindered by the prairie fires. The first statement concerning the proportions of prairie and forest in southwestern Wisconsin seems to be that of Chandler in 1829 on his map of the lead-mining region. He describes the area as nine tenths prairie with the one tenth woodland distributed in groves.

Far and away the most abundant source of material is found in that omnibus class of letters, journals, histories, commercial pamphlets and the notes of military expeditions. It is the best in point of quantity, often in quality, and certainly in point of time since it began in 1670 or earlier and continued to date. Nearly all explorers kept notes assiduously, while the reports of most surveyors and military men were augmented by personal journals of a more general nature. These were far more restrained and accurate than the pamphlets, advertisements and maps which naturally accompanied the exploitation of the rich West. The best material of all came from observant immigrants who were often amateur botanists and naturalists. Their knowledge made for accuracy, and from them is obtained the most complete and satisfying idea of prairie and forest relationships.

The prairie docks and cone flowers,

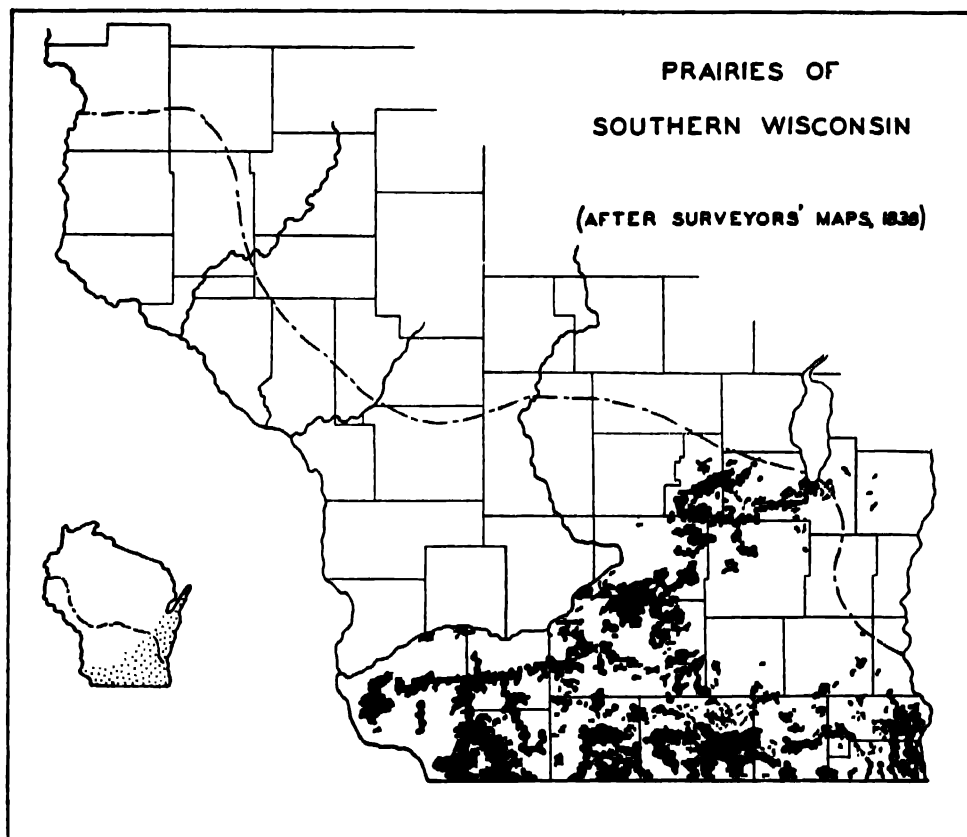


FIG. 3. PRAIRIES RECORDED BY SURVEYORS
EXTENT AND DISTRIBUTION OF PRAIRIE IN THAT PART OF WISCONSIN, INDICATED BY STIPPLING,
WHICH WAS INCLUDED IN THE SURVEYORS' MAPS OF 1838.

blazing stars and goldenrods were referred to only less often than the grasses which formed such an overtowering part of the midsummer landscape. "A sea of grass" was the universal metaphor.

The constitution of the woods depended on the section of the state. Along the lake shore the forest was dense with hard and soft maple, beech, red and white cedar, white birch, two hickories, two walnuts, two pines, tamarack, sycamore, hackberry, poplar, balm of Gilead, aspen, basswood, common and slippery elms, and red, white, burr and pin oaks. On the other hand, farther west a characteristic woods flora included oak, ash, elm, maple, basswood, hickory, butter-nut, black walnut, plum, crab, grape and

the like. Often the woods' floor was so open that it was recommended for horse racing and carriage driving, while the lack of underbrush offered "no impediment to the chase (of deer)." In the northeast "the land inclines to a rolling cast, and is covered with red, white & black oak and the most beautiful groves of sugar maples, without any under-brush."

The rapidity with which woods grew under protection was common knowledge, for though the prairie might be treeless when settled, trees set out for house protection and ornament or for woodlots grew thriftily, almost without exception. A striking example of this is described in the first annual report of the Wiscon-

the Geological Survey on a farm where grew "dense groves of young trees from six to ten inches in diameter, where, twenty-five years ago, not a single shrub could be found larger than a riding-whip." This same process in various localities served to strengthen the conviction that if the prairies were given proper protection from fires for a few years, every farm upon them would have an adequate supply of timber. The source of the new timber would lie in the seeds, roots and stumps sending up new growth after the inhibiting or destructive forces of the prairie fires were removed.

Apparently this phenomenon was the chief cause of a 60 per cent. decrease in the prairie area of southwestern Wisconsin, which occurred between 1829 when Chandler marked it as nine tenths prairie, and 1854 when the Geological Survey reported it was only one third prairie, broken in part by groves and oak openings.

But has there really been a marked increase in wooded territory at the expense of the prairie within historical time? Undoubtedly so, but it has not been accomplished by the natural processes of invasion alone. Before the advent of explorers, regiments and settlers, the successional processes between forest and prairie maintained themselves naturally, and the success of the slowly encroaching woodland seemed to depend chiefly on recurrent prairie fires set by the Indians. However, the man who preempted southern Wisconsin put an end to the fires and disturbed the natural prairie-woods balance. With the cessation of fires there was a tremendous acceleration of woodland growth in those areas where fence lines furnished an early protection. This prodigal increase in wooded area, aside from the plantings that thrived around farm houses and along roadsides, was soon limited to woodlots and windbreaks, but not before the wooded aspect of the country had

become quite pronounced. Then, too, man's occupation soon destroyed the prairies that were open to invasion. It was not long before there was no spot where one could be out of sight of trees.

A hundred and sixty years ago Jonathan Carver climbed one of three limestone outliers in southern Wisconsin known as Blue Mounds and recorded that he "had an extensive view of the country (where) for many miles nothing was to be seen but lesser mountains, which appeared at a distance like haystacks, they being free from trees." Scarcely seventy years ago, a Mrs. John Kinzie passed by the Blue Mounds on the way to Chicago and lamented that it was a country without landmarks, where "one elevation is so exactly like another, that if you lose your trail, there is almost as little hope of regaining it as of finding a pathway in the midst of the ocean." To-day one looks from the Blue Mounds over a sea of green trees broken by fields and pastures and probably never thinks that once it was all a treeless prairie, save for short deep valleys running north to the Wisconsin River.

However, the country is made picturesque by evidences of the encroachment of the woodlands. Wide-spreading burr oaks stand alone in the middle of cornfields. Woods in winter show straight, high-branched trees stretching up between old oaks whose branches start six, ten, twenty inches from the ground, telling of growth in the open, unhampered by surrounding trees.

Encroachment of the forest in southern Wisconsin to-day is a limited process, pushed to fence corners and the edge prairies on bluffs too steep for pasturing or plowing. The landscape, rich in oak and hickory, maple and linden, is indeed a far cry to the time when the people who came to Wisconsin found one of the greatest drawbacks to travel was the lack of sufficient wood to build a campfire.

BOOKS ON SCIENCE FOR LAYMEN

ROCKS FOR LAYMEN¹

THIS book is a new member of the natural history series and brings to an even dozen the series designed to enlighten the interested reader concerning the forms of nature with which he is in daily contact. This is the first book to deal with inanimate objects, and all persons working in geology will be pleased to see the well-known set expanded to include this science.

Geology and the story of its processes, as shown by rocks, does not lend itself to the same type of description as do some of the other natural sciences, perhaps because no readable accounts of life habits can be given. Hence, it is not exactly proper to compare this volume with others of the set; yet being one, it must be considered as intended to cover geology from the same approach as the other texts have their respective subjects.

The first five chapters of this text do not read as smoothly as the last fifteen chapters, the reason being that a considerable amount of factual information, such as physical properties of minerals, as well as types and varieties of igneous rocks, etc., is included. However, the incorporation of this material is necessary and rightly belongs to the first portion of the text. It is apparent to a reader that the authors are much more at ease with the subject-matter in the last chapters than in the first five.

The book is well illustrated and the plates for the most part are very good. One of the four color plates is excellent; the others are not outstanding. In almost every case it is possible for a person familiar with the subject to identify from the illustrations the mineral, rock or physical feature without referring to the legends. This is certainly something which can not be said regarding many texts dealing with rocks and minerals.

¹ *The Rock Book*. C. L. Fenton and M. A. Fenton. Illustrated. xx + 357 pp. \$6.00. September, 1940. Doubleday, Doran and Company.

The reader will find it most annoying to be constantly leafing to another portion of the book to see the illustration of the subject described on the page being read. Text and illustrations could not have been more perfectly separated had a definite effort been made to keep them apart.

Since it is necessary for authors of books of this nature to use concise outlines for complicated geological processes, they can not be expected to please all readers by their statements of these complex problems. This reviewer does not think it important to cite cases in this book where perhaps a slightly different statement of processes could have been made. To do so would be quibbling about details. A surprisingly large number of geological terms has been covered, and to do this in 348 pages naturally it has to briefly dispose of most topics.

This reviewer believes it might have proven more desirable had the authors taken a subject more restricted in scope. In fact, it is thought the authors erred in selecting the title for the book; also in attempting to cover such a wide and varied field in one volume.

The publishers of this series once thought it desirable to issue two volumes on the same class, namely, one treating butterflies and the other moths. These two insects are frequently confused by most people and only the specialist can distinguish them. Hence if two separate texts were necessary in that case the title of "Rocks" would certainly warrant that two volumes should be prepared.

In "The Rock Book" the authors have not only briefly discussed most of the major types of rock, but have covered many features of physical geology as well and have included a chapter on meteorites and one on ores. A worthy improvement could have been made if the subject-matter had been expanded and discussed in two volumes. Perhaps, then, a few

more chapters could be devoted to ores. As it is now, the ores of the different elements are mentioned but not properly developed and this might be of greater interest to the readers than some of the included descriptions of rather unimportant rock types. A definitely more readable and authoritative account could then be prepared which would make this book of value to the student of geology, as well as to the amateur collector and to the more serious-minded traveler for whom this work seems to be prepared.

This reviewer does not wish to convey the impression that his opinion is entirely uncomplimentary. There may be good reasons why so many geological terms should be developed and discussed in one volume. For example, persons knowing little of geology can find in this book an informative account of things they see in the field.

The layman who is interested in better understanding the country over which he travels, likewise the amateur collector, will no doubt find this a good book for his library and one to which he will frequently refer. It is assumed, however, that the text was written for amateurs. For them it is a good field guide. It is hoped that all persons making rock and mineral collections will pay special attention to the authors' concluding chapter where good advice is offered as to both the purpose of collections as well as the manner in which records should be kept.

E. P. HENDERSON

THEY LET THEIR LIGHT SHINE¹

FROM ancient times light produced by living organisms has been thought of as something mysterious. Many have studied it and much has been written, but it remained for Dr. Harvey, who has been a student in this field for many years, to bring together in one book the results of studies which deal with all angles of the problem. This book, "Living Light,"

¹ *Living Light*. E. Newton Harvey. Illustrated. 266 pp. 1940. Princeton University Press.

first discusses the problem of cold light in general, a discussion which all interested in the topic should read. Next is brought together information about those organisms which have the power of producing light, and there are many more of them than most persons realize. At least eleven different phyla have some forms which are capable of luminescence. Not all do so in the same way, and various types of organs are found.

The types of luminescence are classified according to origins and their characteristics are described. Special chapters are devoted to the chemistry and physiology of luminescence and the works of many authorities carefully evaluated. The chapter on the physical nature of animal light is especially interesting, for in it are discussed the means of light measurement and the amount of energy involved. Is it true that the light of a firefly is much more efficient than that of an electric light? How is this determined? These questions and many others are answered.

All in all the book is a very valuable contribution, for in it are brought together the results of the researches of many workers in many fields, each approaching the problem from the special angle of his interest. The results are evaluated and coordinated so that they are available to any one who is interested. One may know what has been done, what has been attempted and what needs to be done. Dr. Harvey has demonstrated that the physical and chemical fields can contribute much to that of biology, always providing that the biologist has the ability to use them. Dr. Harvey has this ability.

D. B. YOUNG

SEA ANIMALS—TOO WONDERFUL¹

PERHAPS it is not fair for one trained in science to review a book in his subject which is written purely as a popular

¹ *Wonder Creatures of the Sea*. A. H. Verrill. Illustrated. xix + 272 pp. \$3.00. May, 1940. Appleton-Century Company.

treatise. However, the general public should be entitled to the opinion of one who is deemed capable of passing upon such a work, verifying the authenticity of the material contained therein.

It is deplorable that more popular scientific accounts are not written by the scientists themselves. Science owes the general public this service, for what scientist is not supported directly or indirectly by the general public? It would also be good for the scientist to be required to put forth an account of his field in simple language.

A. Hyatt Verrill in his "Wonder Creatures of the Sea" follows the frequent procedure of writers of popular books of taking scientific facts and enlarging upon them until a goodly portion of the book becomes fancy.

The author also follows the general trend of such writers of interjecting into the text the human element to the extent that some of the more lowly forms of life, those without even any centralization of the nervous system, experience such sensations as stomach ache and hypnotic influence.

There is little reference to size in the book. One might easily form the opinion that copepods, sea-spiders (pycnogonids) and many of the crabs are of about equal size.

Although the book contains many interesting facts about marine animals, how is the reading public to know where fact ends and fancy begins? The book may be interesting reading, but it can scarcely be recommended from an educational point of view.

G. E. MACGINITIE

EXERCISE FOR HEALTH¹

EXERCISE, like so many other things, can be used with benefit or abused with resultant harm. The value of exercise, in both the positive and the negative sense, depends upon the degree of good

¹ *The Physiology of Exercise*. James H. McCurdy and Leonard A. Larson. Third edition, 349 pp. 1939. Lea and Febiger.

sense with which it is taken. This, in turn, must be based upon knowledge concerning the effects of exercise. At this time when the maintenance of physical fitness becomes increasingly an obligation to the commonwealth, it is particularly fitting that there should appear a thoroughly revised edition of a text on the physiology of exercise. Different types of exercise are well analyzed and the comprehensive discussions of the effects of exertion upon the circulatory and respiratory apparatus are sound. The physiology of muscular action is adequately presented.

The effects of special types of muscular exercise upon bodily functions are considered in relation to age. The special questions arising with adolescents and with people over forty years of age are discussed separately. The advice regarding limitations imposed by aging is good and should be heeded especially by two groups of middle-aged men: Those who refuse to admit that senescence has depreciated their capacity for violent games and who insist upon intense activity after long periods of sedentary softening, and secondly, those who use their age as an excuse for indolence. Either extreme is unwise. There is a refreshing lack of prejudice on the part of the authors; so many volumes on sports or exercise are woefully asymmetric in their viewpoint.

The book is particularly recommended to all those who have active responsibilities in connection with exercise or sports, such as educators, student health physicians, industrial hygienists, gymnasium directors and instructors, and officers responsible for the training of military personnel, as well as those whose interests in exercise are more personal. It will not interest the Big Muscle Men of the Health Club type; it is too sane. The authors have succeeded in presenting much valuable information in a highly digestible form.

EDWARD J. STIEGLITZ



SIR CHANDRASEKHARA VENKATA RAMAN

THE PROGRESS OF SCIENCE

FRANKLIN MEDALISTS FOR 1941

THE Franklin Institute, in its annual award of medals, bestowed its highest honor, the Franklin Medal, this year upon two distinguished scientists, one foreign and the other American. The foreign recipient was Sir Chandrasekhara Venkata Raman, the eminent Indian physicist and Nobel prize winner in physics for 1930, who is most famous as the discoverer of "the Raman effect." But the award of the Franklin Medal was not made for any single experimental result of outstanding importance. The citation states that it was "in recognition of his many brilliant contributions to physical science and of his leadership in the renaissance of scientific work and scientific education that has occurred in India during the last thirty years."

Thirty years ago a scientific career offered little inducement to a young Indian, so that Raman was forced by circumstances rather than by tastes to enter the government service. While serving in the Indian Finance Department he devoted his leisure to the pursuit of scientific interests, and during the years between 1907 and 1917 he contributed thirty original papers to British scientific journals.

These papers established his reputation as an original thinker and, in 1917, when the Palit professorship of physics in the University of Calcutta fell vacant, the chair was offered to him. Since he was appointed to this position, Raman and his collaborators have contributed more than six hundred titles to the literature of sound, musical instruments, ultra-sonics, diffraction, meteorological and colloid optics, photo-elasticity, x-ray diffraction, electro- and magneto-optics, and dielectrics.

In 1921 Raman began work upon the scattering of light, and within three

years had attained such eminence in the field that he was invited to open a symposium on the scattering of light at the Toronto meeting of the British Association. Four years later his researches into this subject led to the discovery of the phenomenon that bears his name—the Raman Effect.

The effect is described by Kastler¹ as follows: "When a homogeneous and chemically defined substance is irradiated with monochromatic light, part of the energy of light is subtracted from the incidental pencil and diffused by the molecules. The most important part of the scattered light is that possessing the same frequency as the incidental radiation (Rayleigh line), but a definite fraction of the energy of light which is scattered by the molecules undergoes a change of frequency (Raman Effect)."

The first studies of the effect were largely theoretical, representing attempts to fit the new phenomenon into theories of radiation and of the structure of matter. Later studies have utilized the phenomenon in the investigation of the constitution and structure of chemical compounds.

Raman's great ambition has been to make India a force in the scientific world. For the past twenty-five years all his talents have been dedicated toward that end. More than one hundred young scientists trained and inspired by him occupy strategic positions in the scientific and educational life of India. Nearly every institution in India devoted to research and education in science has benefited by his influence and support. The brilliance of his researches, the international character of the recognition of his work, his success

¹ "The Raman Effect and Multiple Scattering of Light," by A. Kastler. "Jubilee Volume of Original Papers," Proceedings, Indian Academy of Sciences, November, 1938, p. 476.



MAJOR EDWIN H. ARMSTRONG

as a teacher, his ability and success in founding journals for the publication of scientific work in India, are among the factors which have profoundly influenced the progress of science in his native land.

The other Franklin Medal was awarded to Major Edwin H. Armstrong in recognition of his "pioneer work in Regeneration and the Oscillating Vacuum Tube Circuits, in the invention of the Super-heterodyne Circuit, the Super-regenerator, and a system of Wide Swing Frequency Modulation, each an outstanding contribution to the communication art."

With the collaboration of the late Professor J. H. Morecroft, he applied the oscillograph to the investigation of the nature of the currents and voltages in the audion circuit. Upon finding alternating current components in the plate circuit, he reasoned that these could be augmented by tuning, which was a general technique in radio frequency circuits. Upon inserting a tuning coil in the plate circuit he discovered that the amplification was enormously improved and could be increased to the point where a continuous oscillation in the circuit was obtained.

Realizing the limitations of the tuned radio frequency receivers, Armstrong achieved a great forward stride in building a sensitive, stable, high-gain, low-frequency amplifier of fixed tuning, employing components and technique that were well known. He then, by using the heterodyne principle of Fessenden, converted the incoming high frequency signals to the relative low frequency to which his amplifier was tuned.

In 1922 Armstrong presented before the Institute of Radio Engineers a paper entitled "Some Recent Developments of Regenerative Circuits." This was the first publication of his super-regenerative method of reception. This paper describes methods by which the effective resistance of a regenerative circuit may be made periodically positive and negative, though predominantly positive. Oscillatory circuits consisting of inductance and capacitance have a certain amount of resistance—positive resistance. This is the reason why free electrical oscillations in such circuits are damped. When such a circuit is connected to a regenerative vacuum tube, the feeding-back of energy from the tube's output to its input circuit will effectively wipe out the positive resistance of the oscillatory circuit. When the resistance changes from positive to negative, due to the feeding-back of more and more energy, the circuit becomes self-oscillatory.

The fight of science against radio com-

munication's greatest foe—"static"—began years ago. Many investigators gave it up in despair, arguing that, since the radio waves set up by electrical disturbances were of the same character as those from the transmitter, it was impossible for the receiver to differentiate between them and remain unresponsive to static while reproducing signals. Armstrong spent several years on this problem before he evolved the method that led to success. His triumph lay in transmitting and receiving a type of signal that possessed characteristics which differed from static—which is an amplitude-modulated impulsive wave.

Already this new method of radio communication has made possible the successful relaying by radio (not over wire lines) of broadcast programs through four or more stations linking New York city with various stations in New England. Such a multi-step relay system yields speech quality equal to or better than that furnished by the usual broadcasting toll wire service. The successful relaying of television pictures has also been conducted. F-M greatly improves the important factor of understandability in services such as police radio, aircraft and tank corps radio services, and it offers millions of listeners increased musical enjoyment. It has the features of a revolutionary improvement.

HENRY B. ALLEN,
Secretary and Director

THE FRANKLIN INSTITUTE

NATIONAL NUTRITION CONFERENCE FOR DEFENSE

At President Roosevelt's request a conference of nine hundred delegates convened in Washington, D. C., the latter part of May to explore and define our nutritional problems, to assist in the formulation of a national nutrition policy and to map out recommendations for an immediate program of action. The importance of the nutritional status

of the people in relation to our program of national defense was expressed in the President's message to the delegates, which is quoted here in part:

... During these days of stress the health problems of the military and civilian population are inseparable. Total defense demands man power. The full energy of every American is necessary. Medical authorities recognize completely that efficiency and stamina depend on

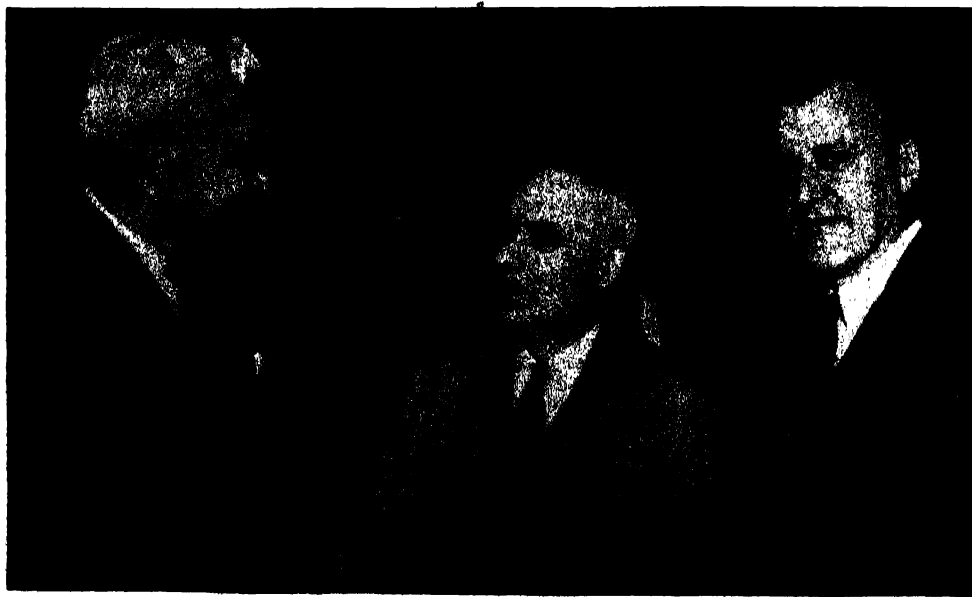
proper food. Fighting men of our Armed Forces, workers in industry, the families of these workers, every man and woman in America, must have nourishing food. If people are undernourished, they can not be efficient in producing what we need in our unified drive for dynamic strength. . . .

The need for unified action on the nutritional front is evident in the face of such facts as the following: Dietary surveys made in the U. S. Bureau of Home Economics have shown that some 45 million persons in this country have diets which would be considered definitely inadequate even when measured by the most conservative standards; as many more persons have diets that rate only fair by the same standards. Intensive clinical investigations of nutritional status made by various agencies, and employing every appropriate measure known to science, have disclosed many cases of specific nutritional diseases. These diseases are due to the use of diets extremely low in one or more vitamins, or in certain minerals. Pellagra, beriberi, scurvy, rickets, keratitis and a number of other recently defined

vitamin deficiency diseases, as well as anemia and tetany, all exist to some extent in the United States.

But far more numerous than the patients suffering from well-defined dietary deficiency diseases are the borderline cases—persons suffering from “hidden hunger” because they have lived for weeks, months or years on diets that are below the safety line. Chronic fatigue, nervous irritability, shifting aches and pains, certain kinds of digestive disturbances, bad teeth, lack of muscular vigor and many other below-par conditions interfere with efficiency and destroy the feeling of well-being.

The prevention and treatment of nutritional diseases and of borderline states of undernutrition are of major importance in making the country strong for defense. If America is to be well nourished, if nutritional deficiencies, major and minor, are to be wiped out, ways and means must be devised for every family and every individual to have a diet that measures up to accepted nutritive standards.



PRINCIPALS OF THE NUTRITION CONFERENCE
PAUL V. McNUTT, M. L. WILSON AND DR. RUSSELL M. WILDER.

These are briefly the problems faced by Mr. Paul V. McNutt, in his capacity as coordinator of health, welfare, nutrition, recreation and related activities in the Federal Office for Emergency Management. His advisory committee of government specialists, with M. L. Wilson, director of extension work in the Department of Agriculture, has been at work for many months assembling information and formulating preliminary plans for a program for nutrition in relation to national defense. Nutrition committees in practically every state have meanwhile been working on programs to meet local situations under the leadership of Dr. Helen S. Mitchell, director of nutrition for Mr. McNutt. When it came to setting up an action program for the entire country, it was realized that no federal group could do the job, and that coordination of state efforts was important. Thus the National Conference on Nutrition for Defense was called, with a number of representatives from each state and a number of government specialists. The conference was divided into nine specialized working sections, and each delegate was assigned to a specific section according to interests and background. The problems to be solved were given over to these sections for analysis. These sections functioned in the democratic way, with discussion from the floor led by chairmen who are authorities in their special fields.

In opening the first general session, Mr. McNutt as chairman outlined the great responsibility he was placing on the delegates, and made it clear that he wanted not oratory but an action platform. He summarized nutrition and welfare problems, and Dr. Russell M. Wilder, of the Mayo Clinic, followed with a strong emphasis on medical aspects. During the conference Vice-President Wallace set three special goals: wiping out deaths caused by dietary deficiencies; a great reduction in those dis-

eases such as tuberculosis, towards which insufficient food predisposes; and making sure that every one in the United States has in his diet enough energy, enough bone, blood and muscle-building food, enough vitamins, to give that feeling of "health plus."

Representatives of various government departments concerned with the problems under consideration outlined the policies of their agencies as related to a national nutrition program. Outstanding authorities in the fields of nutrition and public health summarized recent findings that could be applied in working out recommendations.

A special committee on food and nutrition appointed last fall by the National Research Council, with Dr. Russell M. Wilder as chairman, had been assembling technical information which could serve as a basis for the formulation of policies. This committee presented to the conference a chart of recommended daily allowances for ten nutrients. These allowances are higher in vitamin content, especially in thiamin, nicotinic acid and riboflavin, than nutritive standards previously accepted. In presenting the chart to the conference, Dr. Wilder said: "If America is to have the healthy people we need in this national emergency, we must improve our diets so that they more nearly measure up to this new yardstick for nutrition." The new yardstick was adopted by the conference.

The recommendations for action programs were presented by the sectional chairman for the consideration of the total conference group and were summarized for presentation to President Roosevelt.

Every person professionally trained in medicine, public health, nutrition, dietetics, nursing, social service and all allied fields should be mobilized for nutrition-in-defense work in their own communities. Lay leaders should be trained to assist in the tremendous job of enlist-



SOME MEMBERS OF THE BOARD OF DIRECTORS OF THE NATIONAL SCIENCE FUND
PHOTOGRAPHED AT THE ORGANIZATION MEETING AT THE END OF APRIL. *Left to right:* DR. WILLIAM J. ROBBINS, DR. HARLOW SHAPLEY, DR.
KARL T. COMPTON, DR. FRANK B. JEWETT, DR. ALBERT F. BLAKESLEE, DR. DOUGLAS JOHNSON AND DR. ROBERT A. MILLIKAN.

ing the interest of every citizen in his own nutritional status, and in emphasizing to the general public the importance of good nutrition in relation to health and to total defense.

An increased program of the Department of Agriculture's Surplus Marketing Administration will enable many families through the Food Stamp Plan and many needy school children through expansion of the free lunch program to be better nourished.

Increased opportunities for employment, more adequate housing facilities, stabilizing of prices for essential goods

and services, were also discussed as practical means of putting across an all-American program for better health and vigor.

These are only a few of the challenges offered to the conference delegates to be relayed to groups back home who will work on a state, county or local level. The importance of coordinated effort of all existing agencies at all levels was emphasized and re-emphasized, in doing the job at hand—making Americans strong for defense.

ROWENA S. CARPENTER

BUREAU OF HOME ECONOMICS,
U. S. DEPARTMENT OF AGRICULTURE

THE NATIONAL SCIENCE FUND

THE National Science Fund was established by the National Academy of Sciences at its recent annual meeting for the primary purpose of providing an organization to which any person, foundation or corporation may entrust funds for the advancement of science with assurance that they will be used wisely and fruitfully. The new organization was launched after a three-year study of the present sources of financial support for fundamental researches in science by a committee of The National Academy of Sciences, under the chairmanship of Dr. Albert F. Blakeslee.

The National Academy of Sciences was incorporated in 1863 by an Act of Congress which was approved by President Lincoln. In accordance with the terms of its charter it has often responded to requests from the government for advice on scientific matters. In 1916 the academy greatly increased its ability to serve the government and the country by organizing the National Research Council at the request of President Wilson. Now it has extended the range of its activities still further by setting up the National Science Fund to receive and administer funds dedicated to the support of scientific research.

Direction of the new organization is vested in a board of directors consisting

of four *ex-officio* members, seventeen elected members from the academy and twelve distinguished citizens who are not members of the academy. The members of the board are as follows:

Ex-officio members: Dr. Frank B. Jewett, president of the Academy, Dr. Jerome C. Hunsaker, treasurer of the Academy, Dr. Ross G. Harrison, chairman of the National Research Council, and Dr. Irving Langmuir, president of the American Association for the Advancement of Science.

Members from the Academy: Professor Roger Adams, Dr. James R. Angell, Dr. A. F. Blakeslee, President Isaiah Bowman, Professor Arthur H. Compton, President J. B. Conant, Professor Edwin G. Conklin, Dean L. P. Eisenhart, Dr. Herbert S. Gasser, Herbert C. Hoover, Professor E. O. Lawrence, Professor Frank R. Lillie, Dr. Robert A. Millikan, Dr. Alfred N. Richards, Dr. William J. Robbins, Dr. Harlow Shapley and Dr. G. H. Whipple.

Members of the board who are not members of the Academy: Winthrop W. Aldrich, chairman of the Board of Chase National Bank, James F. Bell, chairman of the Board of General Mills, Inc., Hon. John W. Davis, former Ambassador to Great Britain, Homer L. Ferguson, president of Newport News Shipbuilding and Drydock Company, Walter S. Gifford, president of American Telephone and Telegraph Company, Dr. Carlton J. H. Hayes, professor of history in Columbia University, Dr. Archibald MacLeish, librarian of the Congressional Library, Harvey S. Mudd, president of Cyprus Mines Corporation, Elihu Root, Jr., lawyer, Tom K. Smith, president of Boatmen's National Bank (St. Louis), Lewis L. Strauss, partner in Kuhn, Loeb and Co., and Harold H. Swift, vice-

chairman of board of Swift and Company and chairman of board of trustees of the University of Chicago. Dr. William J. Robbins, director of the New York Botanical Garden, was designated acting chairman of the board.

Although the National Science Fund is empowered to receive and administer funds for the support of scientific research, it will not enter immediately on a "drive" for large sums. It will, instead, formulate basic principles and machinery of operation deserving of the confidence of great numbers of persons who will desire to contribute to the advancement of civilization through science.

There is a general impression that gifts in support of science and education in the United States are rapidly declining. As a matter of fact, such is not the case. All the thirty great foundations have been established since 1900 and fourteen of them since 1920. The Rackham Foundation, with an endowment of \$12,500,000, was established as recently as 1933.

The purposes of these great foundations are to promote human welfare in

various ways. For example, the stated purpose of the Rockefeller Foundation, established in 1913, is "to promote the well-being of mankind throughout the world." The Children's Foundation of Michigan, established by Senator James Couzens in 1929, was "to promote the health, welfare and happiness of the children of the state of Michigan and elsewhere in the world." The Duke Foundation of \$40,000,000, established in 1924, was to promote "the needs of mankind along physical, mental and spiritual lines" in the South. The total assets of these great foundations amount to about \$700,000,000, and the amounts expended by them to date for the purposes for which they were organized are approximately \$900,000,000. In addition there have been hundreds of large gifts every year in support of universities, colleges, libraries and other institutions organized for public good. In view of these great and continuing gifts, the National Science Fund will almost certainly receive generous support.

F. R. M.

DEMONSTRATION OF THE EFFECT OF RADIATION ON ORGANISMS AT THE SMITHSONIAN INSTITUTION

On his tour of the Great Hall of the Smithsonian Institution, the visitor will see, in the fourth alcove, a cross section of the activities of the Division of Radiation and Organisms. This division gives practically its entire time to the study of radiation as it affects living things.

The central motif is seen on the middle panel (Fig. 1). Here is shown a diagram two meters long of the great electromagnetic spectrum extending from the short cosmic rays, through the x-rays and ultraviolet to the visible, then into the infrared and the radio waves. The visible, or central, portion is enlarged and shown below the diagram in the form of an actual spectrum from a grating.

In the panel to the visitor's right are

exhibits which illustrate the effects of light on plants. The first is a working schematic diagram of a plant (right side of Fig. 4). Here is illustrated the movement of water through the plant stem from root to leaf, where it evaporates. This loss of water is technically called "transpiration." Another leaf illustrates respiration, in which small particles of "carbon dioxide" are shown escaping from the plant and small particles of "oxygen" entering. A third leaf illustrates photosynthesis, that fundamental process taking place in green plants whereby carbon dioxide is absorbed from the air in the presence of light and is converted into sugar and starch. The visitor may press a button and see the leaf absorb "carbon dioxide"

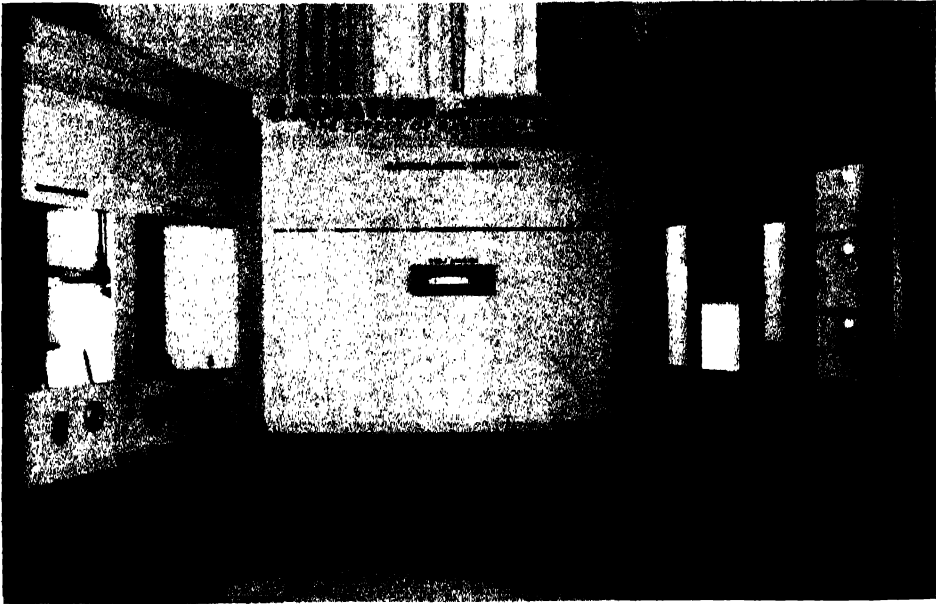


FIG. 1. EXPERIMENTAL EXHIBITS OF THE DIVISION OF RADIATION AND ORGANISMS

and give off "oxygen" as the "plant" is illuminated.

In the second compartment (left side of Fig. 4) are three "plants," each illuminated from one side by a different colored light. This illustrates phototropism, or the growth reaction to light. Plants grown where they receive light from one side will bend toward the light. To obtain symmetrical growth they should be turned or rotated. Here one

sees that it is the blue component of white light that is most effective, that green light is less effective and that red light has no effect at all in this growth response.

The central exhibit of this panel is a working model of a plant growing under different light intensities. When the visitor presses the button, he will note that as the light diminishes in intensity the plant grows taller.

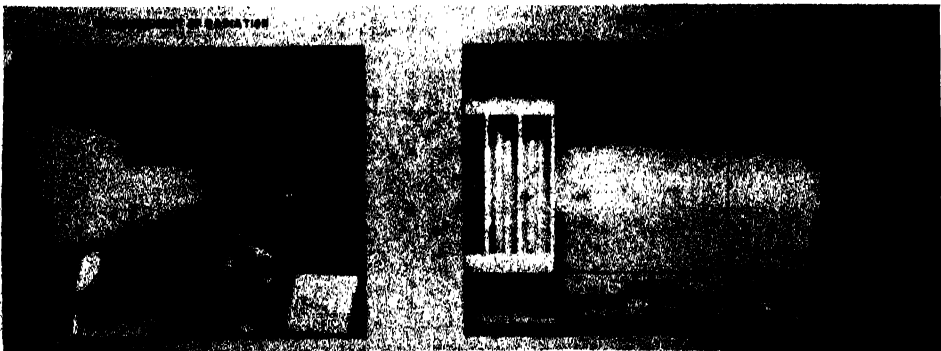


FIG. 2. MEASUREMENT OF RADIATION AND SOURCES OF COLORED LIGHT
THESE COMPARTMENTS ILLUSTRATE METHODS OF MEASURING RADIATION AND OBTAINING SPECIFIC WAVE-LENGTHS OF LIGHT.

The next space to the left is given over to the actual growing of algae on nutrient agar and in nutrient solution under artificial light. When the button is pressed, an enlarged image of an alga is thrown on a white screen in the upper



FIG. 3. EXPERIMENTAL GROWTH CHAMBER

FOR GROWING ROOTS IN NUTRIENT SOLUTION UNDER CONTROLLED CONDITIONS OF HUMIDITY, TEMPERATURE AND LIGHT.

compartment. Algae are the simplest forms of green plants, varying in size from microscopic single cells to multicellular forms many feet long. Because of their simple form, complete with all the life processes found in higher plants, algae are convenient for scientists to use in their researches on the effects of light, temperature and other environmental factors on photosynthesis, respiration and related plant processes.

The last plant exhibit (Fig. 3) illustrates one method used in the laboratory for growing plants under experimental conditions. Plants such as wheat and barley are grown with their roots in nutrient solution and their tops in a double-walled glass tube where the temperature and humidity are controlled. To equalize illumination the plants are slowly rotated before light of known intensity and wave-length. The effects of different intensities and colors of light on chlorophyll formation, photosynthesis and respiration can thus be studied under controlled conditions.

The left-hand panel (Fig. 2) is given over to some physical methods that have been used in connection with plant and animal experimentation. As the visitor faces this panel he sees in the compartment on the right several devices for obtaining lights of various colors or wave-lengths. By pushing one of the electrical switches a beam of white light is sent through a prism and broken into the colors of the spectrum. The operation of a small disk will cause a slit to pass across this spectrum and the operator may select any color to be thrown on the small rear screen.

Another push button operates a lamp which sends beams of light through three different filters, glass, Christiansen and liquid. A colored glass filter absorbs certain colors and transmits others. A red glass filter, for example, absorbs violet, blue and green, and permits red light alone to pass through. This is also true of colored solution filters, with the

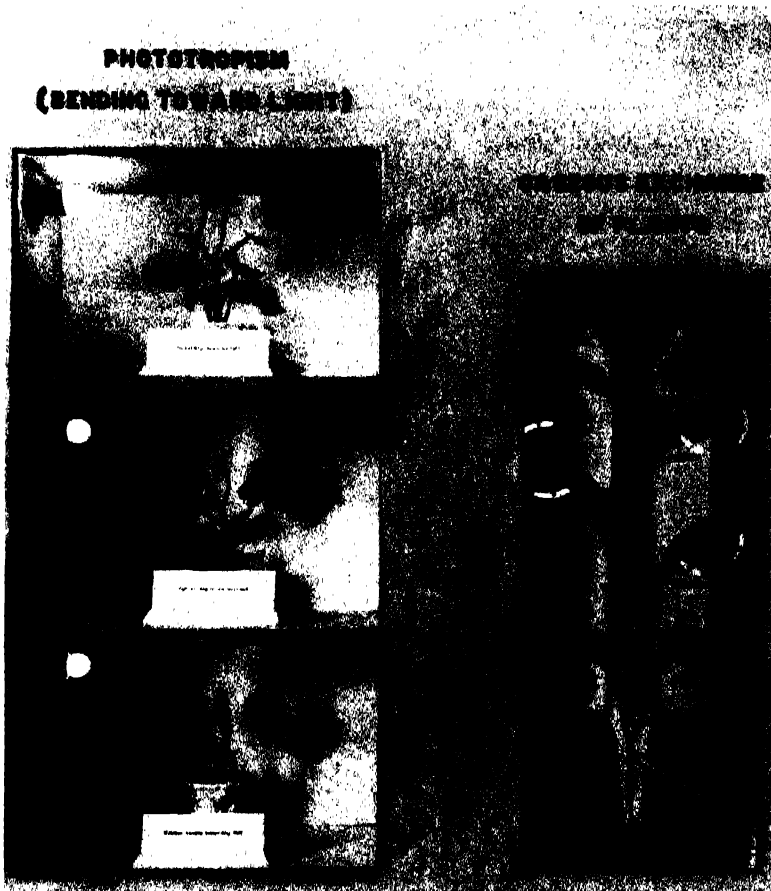


FIG. 4. DEMONSTRATIONS IN PLANT PHYSIOLOGY

THE LEFT COMPARTMENT ILLUSTRATES GROWTH OF PLANTS TOWARD LIGHTS OF DIFFERENT COLORS: RED, GREEN AND BLUE. THE RIGHT COMPARTMENT ILLUSTRATES THE MOVEMENT OF WATER UP THE PLANT STEM, THE EVAPORATION OF WATER FROM THE LEAF AND THE EXCHANGE OF CARBON DIOXIDE AND OXYGEN IN RESPIRATION AND PHOTOSYNTHESIS.

advantage that many shades and depths of color may be obtained by dilution and concentration. The Christiansen filter provides colored light in another way. A mass of small glass particles is immersed in a liquid having the same refractive index as the glass for the desired color. Since no light of this color is reflected or refracted (bent) at each small glass surface, this color is freely transmitted and is brought to a focus by the lens. All other colors are reflected or changed in direction and so are lost.

Another method of obtaining colored

light is the use of discharge tubes. The visitor may operate another electrical switch and light a Neon lamp, in which the neon atom emits only red light when subjected to high voltage excitation; a mercury vapor lamp in yellow glass which transmits the yellow-green wavelengths; and a fluorescent lamp which makes use of the fact that some materials emit visible light (fluoresce) when exposed to ultraviolet rays.

The other compartment (on left of Fig. 2) in this panel shows certain types of apparatus for the measurement of

radiation. A button operated by the visitor turns on a lamp that directs a beam of light to the receiver of a thermocouple, where it is converted into heat. This energy is converted into electrical energy that activates a galvanometer, and the intensity of the light is measured on a scale. By turning a small disk different colored glass filters may be in-

terposed in the beam of light and the relative transmission of these filters measured.

Other instruments shown here are photoelectric cells of the barrier type and the emission type, and the bolometer, a Smithsonian-developed instrument for the measurement of radiation.

EARL S. JOHNSTON

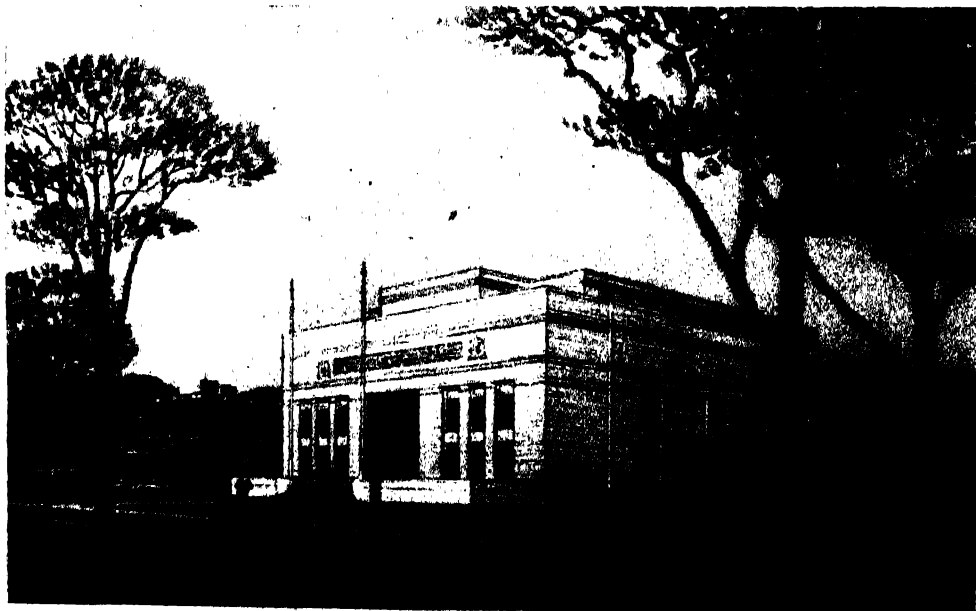
BAUSCH HALL OF SCIENCE AND HISTORY OF THE ROCHESTER MUSEUM

THE forward-looking plans of the Rochester Museum of Arts and Sciences have been greatly advanced through a gift by Edward Bausch, the microscopist, of funds for the erection of a new central unit. This building, which is now nearly completed, has been named the *Bausch Hall of Science and History*, the cornerstone having been laid on April 23, 1941, by Dr. Robert A. Millikan.

The building was designed especially to house the laboratories, studios, workshops and offices of the museum staff and will be equipped with the modern elec-

trical devices and instruments necessary to carry on a research laboratory and popular program in the fields of natural science and physics.

The exhibition halls, of which there will be three, will present the story of nature from the phenomena of the stars, the geological ages, the beginning of life and the several phyla, ending at the entrance hall with dioramas of the larger local mammals, including the beaver. The stairway and elevator then convey the visitor to the second floor which, by diorama and exhibit, will tell a story of ancient man in Europe and in America,



ARCHITECT'S DRAWING OF THE BAUSCH HALL OF SCIENCE AND HISTORY



HALL UNDER CONSTRUCTION; PHOTOGRAPHED IN MAY

up to the coming of the white man. The third floor continues the drama of culture by presenting the great episodes in the culture history of western New York. This will be done in a series of alcoves which will portray in miniature and by actual-sized period rooms, the struggle of the pioneer up to the coming of the industrial age. A new wing has been projected to carry on this sequence and describe the progress of science and invention.

By developing a museum of science which merges into the field of culture history and industry, the museum will endeavor to present in cross section the salient features of upstate New York carrying out through its exhibits the inscription which is engraved at the top of the building:

DEDICATED TO A BETTER UNDERSTANDING
OF THE LAWS OF NATURE AND CULTURAL
ACHIEVEMENTS OF
MANKIND

The new central unit will have its own printing plant, its biological laboratory

with many unique features and a radio control station which will include sound recording and television reception.

A mezzanine floor between the first and second floors will house a school service program designed especially for children.

Dr. Bausch has assured the museum commissioners and the director that his desire is to make possible the carrying out of the existing plans which the museum has been attempting to achieve for a number of years.

The new Bausch Hall of Science and History is located in the heart of the residential section, on East Avenue, Rochester, N. Y., and is not far from Eastman House, the residence of the president of the University of Rochester. The Academy of Medicine is also located on East Avenue and is one of the sections of the Rochester Museum. Medical, anatomical and public health exhibits will be placed in the academy.

ARTHUR C. PARKER,
Director

ROCHESTER MUSEUM OF ARTS
AND SCIENCES

SOLAR WHIRLS

TITANIC flowers of fire on the face of the sun, with the dark areas of sunspots as their centers and long filaments of flaming hydrogen gas as their petals, are being studied by astronomers at the Mount Wilson Observatory of the Carnegie Institution of Washington. These great filaments, sometimes forming vortices or whirls long known to solar observers, are the subject of a special investigation by Dr. R. S. Richardson.

The normal surface of the chromosphere, or outer atmosphere of the sun, when viewed with the spectrohelioscope under the best observing conditions, is seen to be finely granulated like the skin of an orange. Near large sunspots, however, there is a marked change in its appearance; the atmospheric gases are drawn out into long filaments, indicating the presence of extensive fields of force.

"Seen under the best conditions," Dr. Richardson says, "these filaments remind one of petals or tendrils growing out of sunspot penumbra and spreading over the hydrogen chromosphere. Occasionally they form a pattern similar to the arrangement of iron filings around a bar magnet, or to the lines of flow in a vortex." These filaments, he warns, must not be confused with the great polar prominences, geysers of fire thousands of miles high, which shoot up from the sun's face. They are smaller and lighter, though sometimes it is difficult to distinguish between the two phenomena.

Well-formed solar flowers are seldom observed. The late Dr. George E. Hale, formerly director of the Mount Wilson

Observatory, found only 51 well-marked examples of them in observations of more than 3,000 sunspot groups between 1908 and 1924. Their cause is still debatable. Sunspots are known to behave like great magnets, and one explanation of them has been that the filaments are produced by magnetic forces. If this were the case, however, the direction of curvature of the "petals" would always be in accord with the polarity of the magnet. The fact that the polarities reverse from one sunspot cycle to the next, while the direction of the whirls *does not reverse*, argues strongly against the magnetic-field hypothesis of the whirls. Another theory, which seems more in accord with the present evidence, is that they are "whirlpools" in the sun's high atmosphere, whose form depends on how the gases are flowing into or out of the spot.

Dr. Richardson's own observations tend to confirm Hale's earlier results, and to support the hypothesis of atmospheric whirlpools. In the northern hemisphere their direction is mostly counterclockwise, like that of cyclones in the atmosphere of the northern hemisphere of the earth. In the sun's southern hemisphere they are mostly clockwise, paralleling atmospheric disturbances south of the earth's equator. If this is true, the inference is that the direction the vortex takes is determined largely by the solar rotation, just as the opposite directions of motion in cyclonic disturbances in the two terrestrial hemispheres are produced by the rotation of the earth.—S. W.

THE SCIENTIFIC MONTHLY

AUGUST, 1941

GEOLOGICAL ASPECTS OF OUR NATIONAL PARKS

I. NATIONAL PARKS OF THE FAR WEST

By Dr. RAYMOND E. JANSSEN

EVANSTON, ILLINOIS

Our great National Parks are sections of the old American wilderness. They are as valuable, acre for acre, as the richest farmlands. They feed the spirit, the soul, the character of America.

—*Emerson Hough*

THE National Parks of the United States, primarily, are areas of scenic magnificence which have been set aside by Congress for the benefit of the people. Almost without exception, the natural features of these parks are unparalleled in the explored world. They have come to be recognized as supreme examples of their kind. Few nations can equal one or more of these masterpieces of nature, and none can boast of containing several of them. And America, too, has assumed leadership in making her countless wonders readily accessible to her citizens—to be enjoyed by rich and poor alike.

The United States can claim without fear of contradiction that she stands pre-eminent in her assemblage of scenic wonders. Yellowstone Park contains more and larger geysers than all the rest of the world together. The Grand Canyon of Arizona is the world's greatest example of erosion by running water. Mount Rainier has the largest single-peak glacier system known. Crater Lake is the deepest and bluest of the accessible freshwater lakes of the world, occupying the

bowl of a former great volcano. Yosemite has long been heralded as the world's most beautiful valley; the quality of beauty can not be measured mathematically, but opinions of world travelers tend to sustain Yosemite's claim. Carlsbad Caverns contain the largest series of underground passages yet discovered. The sheer sculpturing of the many colorful peaks in Glacier Park is not equaled elsewhere in the world. The giant monarchs of Sequoia National Park are the largest and oldest living things in the world. Hawaii National Park may boast the hugest active volcano in the world and the Kilauea Lake of Fire, which is, itself, unique. Mount McKinley in Alaska, also a national park, is scenically the world's loftiest mountain; although peaks of the Andes and Himalayas rise to greater heights, they can not be viewed closely except from valleys at least 5,000 feet higher than McKinley's.

Few, indeed, are the individuals who can gaze into the mysterious depths of the Grand Canyon, peer upward to the jagged heights of the Grand Tetons, or watch the spouting waters of Old Faithful without experiencing some inward sense of emotion—some feeling of awe and wonder at the marvels displayed before them. And yet, how many of these

individuals fully comprehend these amazing spectacles?

To most observers, scenery is a pleasing panorama of mountain chains, deep valleys, turbulent streams, plunging waterfalls, quiet lakes or trackless forests. To them, the glistening peak of Mount Rainier, the ice-gouged valley of Yosemite, the windowed walls of Bryce Canyon or the festooned caverns of Carlsbad are little more than scenery—scenery of such magnitude as to be at once incomparable and undescribable, mysterious and meaningless. And yet, upon those self-same valley walls and eroded mountain sides are the written pages of history, the mighty drama of a constantly changing world.

It was A. C. Seward, the English paleobotanist, who once said, "A knowledge of the past, however imperfect, adds to the attractiveness of the present." The truth of this statement is self-evident.

It is one thing to gaze in awe across the great abyss of the Grand Canyon; but it is far more satisfying to view it in the light of history—to see upon its painted walls the shifting scenes of a pulsating continent, to see in its mysterious depths the motivating power of running water. It is one thing to gaze enraptured upon Glacier's ice-carved mountain sides; but it is much more thrilling to visualize in them the mighty upheaval which changed sea-bottom to mountain-peak, later, to be gouged by the rasping power of creeping rivers of ice. It is one thing to see beauty in a hundred glacial lakes, perched high upon the cirque-etched cliffs; but it is an added experience to appreciate that they owe their continued existence to the morainic dams which hold them in their places.

Only through the application of knowledge can we fully appreciate and understand. To derive the fullest measure of



Courtesy U. S. Dept. of the Interior

MOUNT MCKINLEY, HIGHEST MOUNTAIN IN NORTH AMERICA
 LOOMING HIGH ABOVE THE GREAT ALASKA RANGE. IT RISES 20,300 FEET ABOVE SEA-LEVEL AND 17,000 FEET ABOVE THE GRAVEL PLATEAU IN THE FOREGROUND. EVERLASTING GLACIERS OF ENORMOUS BULK COVER THE MOUNTAIN'S SIDES.

satisfaction from the matchless beauty of our national parks, we must remember that in their present forms they are but ephemeral stages in a constantly shifting drama—a drama whose beginning was never witnessed by man, and whose end is nowhere in sight. To read even a portion of that drama is to add to the appreciation of our scenic wonders.

There are to-day 161 national parks and monuments, occupying more than 33,000 square miles of territory. These national reservations fall readily into two major classes—those which contain natural wonders and those of purely national historical interest. We are concerned here with only those national parks which contain scenic wonders of immense proportions. These may be further divided into several groups on the basis of their geological and evolutionary origins. Three distinct groups may be considered as including the mountain parks of the Pacific Chain, the Rocky Mountain Chain and the Appalachian Chain. Another group includes the desert and canyon parks of the arid Southwest. A fifth group embodies the subterranean parks, such as Carlsbad Caverns, Mammoth and Wind Caves. A final group includes national parks which are of interest solely because of their mineral springs, such as Hot Springs in Arkansas and Platt in Oklahoma.

THE PACIFIC MOUNTAIN PARKS

North America is bordered on the west by the Pacific Mountain System, a broad mountainous chain extending northwesterly from Mexico to Alaska. At the head of Cook Inlet, it swings in a great arc to the southwest, extending to the end of the Aleutian Islands. This great arc is the massive Alaska Range, loftier than the Sierra Nevadas and greater in relief and extent than the Alps.

The central mass of the vast Alaska Range attains its climax in majestic Mount McKinley. It towers to a height

of 20,300 feet, and on clear days the glistening peak can be seen from distances of 200 miles in all directions. Its upper two thirds are perpetually blanketed in ice and snow. This, the highest mountain in North America, was acquired with the Alaska Purchase in 1867. The mountain was surveyed by the United States Geological Survey in 1898, but its summit was not scaled until 1913. In 1917, Congress set aside the territory surrounding the mountain under the name of Mount McKinley National Park. It has an area of 3,030 square miles, and is our second largest park, exceeded in size only by Yellowstone.

The Pacific Mountain Chain had its origin in the great diastrophic movements which occurred at the close of the Jurassic Period, although the present elevations of these ranges are the results of subsequent uplifts, principally at the close of the Tertiary Period. These titanic deformations were intense throughout the chain, from the Aleutian Islands to Mexico. The great Alaska Range, as well as the Gold and Cariboo Ranges of British Columbia, were elevated at this time. Within the United States, the Coast Ranges, the Cascades, the Sierra Nevadas and the Klamath Mountains were born. Accompanying these major uplifts, great quantities of molten magma were welled up into the central portions of these ranges. This frozen magma stands out to-day as great batholiths of granite which have since been uncovered by erosion. Granite is one of the hardest and most common rocks. Because of its massiveness and resistance to erosion, it stands out in towering peaks, lofty ridges and sheer precipices, producing scenery quite different from that of sedimentary and extrusive volcanic rocks. The cores of our Pacific mountains, as well as those of the Himalayas and the Andes, are pre-vaillingly granite. Our Pacific Mountain Chain contains a number of national parks whose exquisite scenery has been



Courtesy Southern Pacific Lines

THE CREST OF MOUNT WHITNEY, HIGHEST POINT IN THE UNITED STATES
UNLIKE THE ISOLATED PEAKS OF MANY OF OUR HIGH MOUNTAINS, IT REACHES ONLY SLIGHTLY
HIGHER THAN THOSE OF ITS SURROUNDING NEIGHBORS. EROSION HAS CARVED THE SUMMIT AREA
INTO A MASS OF JAGGED RIDGES AND PINNACLES.

carved in granite. Included here are Mount McKinley, Olympic, Yosemite, Sequoia and the newly established King's Canyon National Parks. In all these areas, erosion has worn through the up-raised sediments and is now actively carving the granite core of the great Pacific Chain.

Within the United States, the Pacific Chain attains its zenith in the high Sierra Mountains which effect a mighty rampart for a distance of 450 miles along the eastern part of California. Here the massive granite block has been carved during millions of years of erosion into an infinite variety of towering domes and pinnacles, deep canyons and sheer cliffs. The variety of granitic scenery here is remarkable because of the abundance of waters—not rain, but melted snows—which have supplied the cutting power of innumerable streams. Added to this, has been the gouging action of glaciers

which moved down from the heights during the Great Ice Age. Amid this setting is Mount Whitney, 14,495 feet in altitude, the highest point in the United States.

Yosemite, Sequoia and King's Canyon National Park (including the former General Grant National Park) constitute a cross-section of the western slope of the Sierra Nevadas. These three closely adjacent parks include over 2,500 square miles of territory, containing some of the most magnificent scenery and the grandest forest trees of all the world.

Yosemite, acknowledged as the most beautiful of our national wonderlands, takes its name from the Indian language. To the Red Man, Yo Semite—the Grizzly Bear—was king of the forests, even as Yosemite to-day is heralded as king of natural beauty. Its colossal masses of granite (El Capitan and Half Dome), its sheer rock walls rising precipitously

above peaceful valley floors, its gleaming glacial-polished surfaces and its dashing ribbon-like waterfalls all combine to present those qualities which are deemed most beautiful in the eyes of man. And yet, to look upon such scenes as these without reading there the drama of their creation is to miss a great part of the picture.

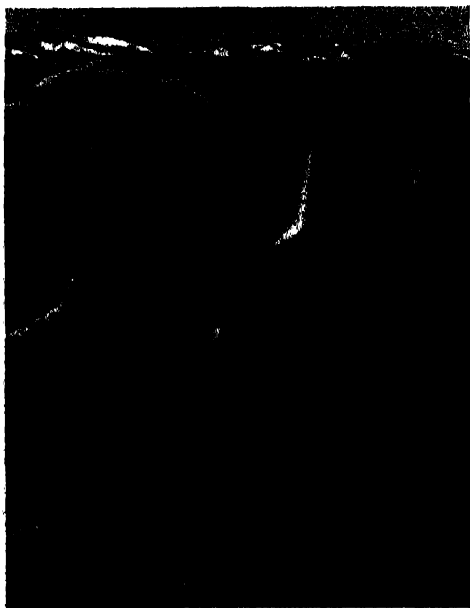
Etched to a depth of over 2,000 feet in solid granite may be found the epic of Yosemite's eventful history. It was Francois E. Matthes, of the United States Geological Survey, who first grasped the full significance of the drama written on those rocky walls. He discovered that the main range of the Sierra Nevadas had been elevated steadily over a long period. The Merced River, armed with sand and boulders, catapulted down the slopes, cutting a deep valley into the granite as the great block was being lifted. The result was

a master V-shaped river valley, with lateral steep-graded valleys entering it at various points. Then came the great glacier, moving slowly down the valley.

At its maximum, the ice came within 700 feet of the top of Half Dome. It overrode Glacier Point, extending below El Portal for about a mile. The ice deepened the valley 500 feet at the lower end and as much as 1,500 feet in the upper portion near Glacier Point. Also, the valley was widened 1,000 feet at the lower end, and 3,600 feet at the upper. The mouths of the various lateral valleys were truncated and left suspended as hanging valleys, perched high upon sheer cliff walls. The lateral streams now reach the Merced River only by plunging over dizzy falls, several of which rank among the highest in the world.

It was long thought that Yosemite Falls, plunging downward for 2,565 feet in a series of two cataracts and several intermediate cascades, was the world's highest; and in much of the literature it is so recorded. But the work of the scientist and the surveyor is never done. We now know that one other, at least, is higher. This is Angel Falls in Venezuela, which makes a single plunge of more than 3,300 feet. If we consider sheer drops only, without taking into account the intervening cascades, then three more known waterfalls are higher than Yosemite's sheer falls of 1,750 feet. These are Kukenaam Falls, also in Venezuela, Sutherland Falls in New Zealand and Tugela Falls in South Africa. But lest we tend to diminish our own glory too quickly, let us remember that the seven highest waterfalls of Yosemite Valley rank among the first forty-seven of the highest known falls of the world. And our seven falls are all within a distance of ten miles from each other! A water spectacle such as this can be seen nowhere else in the world.

The late Tertiary uplift of the Pacific



Courtesy Santa Fe Railway

YOSEMITE FALLS

HIGHEST IN NORTH AMERICA, PLUNGES FROM A "HANGING VALLEY" WHICH WAS LEFT PERCHED UPON A SHEER CLIFF WHEN THE GREAT GLACIER SCOURED OUT THE MAIN VALLEY.



Courtesy Chicago and Northwestern Railway

**MOUNT RAINIER SLUMBERS BENEATH PERPETUAL BLANKET OF ICE AND SNOW
ONCE A BELCHING VOLCANO, NOW UPON ITS SIDES IS THE GREATEST SINGLE GLACIER SYSTEM IN THE
UNITED STATES.**

Chain was accompanied by intense volcanic activity. At many points the upwelled magma pushed through the folded and broken sedimentary layers. The Cascade Mountains, from Washington to California, were folded into a broad arch, and upon this platform are perched numerous volcanoes which once blazed forth as fiery beacons along the shores of the broad Pacific. Mount Hood, Mount Adams, Mount Baker, Mount St. Helens, Mount Rainier, Mount Shasta and Mount Lassen are a few examples. Some, like prehistoric Mount Mazama and Mount Tehama, long ago blew themselves away, and we see to-day only remnants of their former magnificence.

Among our many volcanic mountains, Mount Rainier is heralded as the grandest. Rising to a height of 14,408 feet, it is the third highest mountain within the United States. It stands 11,000 feet

above its immediate base and covers 100 square miles of area. Its colossal magnitude dwarfs the surrounding peaks which, themselves, average more than a mile in height. The inclination of its flanks indicates that at one time it probably reached an altitude of 16,000 feet.

Like all volcanoes, Mount Rainier was built into a cone-shaped mass with materials ejected from its own interior—cinders, lumps of lava and flows of molten magma which solidified into hard layers of andesite. It is believed that a great explosion blew away the uppermost part of the original cone, reducing its height by about 2,000 feet. Within the remaining crater, which is nearly three miles in diameter, two smaller cinder cones were later built up. They rise about 300 feet above the old crater rim and form the present summit of the peak. Mount Rainier has had no great



Courtesy Southern Pacific Lines

CRATER LAKE NOW FILLS THE ENORMOUS CHASM OF A FORMER VOLCANO
ENCIRCLED BY THE BLASTED WALLS. RISING ABOVE ITS MIRRORED DEPTHS IS WIZARD ISLAND, FORMED BY THE CONE OF A SECONDARY VOL-
CANO WHICH AROSE WITHIN THE SHATTERED REMNANT OF THE FIRST.

eruptions during historic periods, but Indian legends tell of one, the date of which is unknown. Although the volcano is now dormant, considerable heat still remains within its reservoirs. Small jets of steam still issue from the summit, and warm springs flow from its sides. Mount Rainier has been a national park since 1899.

Mount Rainier is most famous for its extensive glacier system. Its 28 glaciers approximate 48 square miles in area, an expanse of ice far in excess of that on any other single peak in the United States. Several of these glaciers are from four to six miles in length. They vie in magnitude with the outstanding glaciers of the Alps, among which only one—the Aletsch Glacier—is much greater in size. Six of Rainier's great glaciers seem to originate near the peak, but others have their sources in the snows which accumulate in the bowl-shaped cirques on the mountain's sides.

The scenic effects resulting from the action of mountain glaciers can not be fully appreciated unless the function of the glacier is understood. At the uppermost extremity, or source, the ice freezes against the rock wall of the mountain. As the glacier moves forward, it pulls away—or plucks out—masses of rock which are then carried along with the body of moving ice. The resulting cavity behind the ice is then refilled with freshly fallen snow. This, in turn, becomes compacted into ice and freezes to the rock wall. Continued forward movement of the ice mass, and continued refilling of the crevice with new ice, repeated during innumerable ages, gradually plucks away the rocky mass of the upper mountain heights. Frequently the rock is undermined so that great chunks fall from the upper wall upon the ice and are also carried away. A precipice is left, often sheerly perpendicular. As the process continues, the precipice itself is cut backward into the

very heart of the mountain peak. Such precipices are usually in the shape of an arc, or half circle; hence the name cirque—the starting point of the glacier.

As a glacier moves down the mountain, it also widens and deepens the valley through which it moves, the results of which are so vividly portrayed in Yosemite Valley. Such erosion is largely the result of freezing and plucking away of rock along the sides and bottom of the ice mass. Rocks which are frozen in the under surfaces of the ice act as rasps which scrape along the valley floor. After the glacier has melted, these rasp scratches, or striae, may be seen upon the rock surfaces over which the ice has passed. They provide a criteria in determining the extent and directional movement of former glaciers.

At the lower extremity of a glacier, where the ice is melting, erosional activity is replaced by depositional activity. The rocks, gravel and sand which have been carried down by the moving ice are dropped as it melts. The heaps of resulting debris, or moraines, frequently act as dams and give rise to impounded lakes which are fed by the melting ice-water. As the glacier melts back through successive stages, a long series, or chain, of lakes may thus be formed, each held back by an individual moraine. The highest ones may occupy the actual cirques at the very sources of the former glaciers. Cirque lakes, perched high upon a mountain, and nestled beneath sheer cliffs on one side and held back by low moraines on the other, present many of our beautiful mountain vistas.

Among the innumerable quiet lakes which decorate our Pacific wonderlands, there is one of extraordinary significance. It is not a glacial lake, and the story of its origin is one of the outstanding epics which geology has revealed. Located in southern Oregon, on the very crest of the Cascade Range, is Crater Lake, occupying the bowl of a great volcano long



Loomis Photo. Courtesy National Park Service

EFFECTS OF TREMENDOUS MUDFLOW WHICH DESCENDED LASSEN PEAK ON MAY 19, 1915, PRECEDING THE MAIN ERUPTION, MAY BE SEEN IN THE DEVASTATED AREA WHERE MUCH OF THE FOREST WAS COMPLETELY DESTROYED.

since blown away. Mount Mazama, as it is called, was one of the mighty volcanoes which lighted the midnight skies after these ranges were elevated during the Tertiary Period.

The volcano was built up principally by lava flows, poured out layer upon layer, until a cone 14,000 feet high was attained. Glaciers moved down its sides, carving U-shaped valleys upon its flanks. And then, accompanied by a violent explosion, the volcano seems literally to have boiled over. Frothy lava rushed down the glacial valleys and overflowed the surrounding lowlands for distances up to 35 miles. This lava seems to have poured forth at terrific speed, for much of the molten material did not begin to solidify until it was four or five miles away from the crater. Accompanying these outpourings, or shortly thereafter, fissures developed along the mountain flanks, and the weakened dome collapsed within itself. The yawning crater which

we see to-day is all that is left of the former towering Mount Mazama.

When Mazama collapsed within itself, there was intense reaction within the pit. The crumbling lavas choked the huge vent. In three places within the crater, small new volcanoes were born. Eventually these died and cooled. During succeeding ages, rain and snow blown into the huge crater formed Crater Lake. The rising waters covered two of the small volcanic cones; the third, called Wizard Island, is still emergent. The lake has no inlet, and except for seepage, there is no outlet.

Such a lake was made possible only by a combination of conditions rarely equalled. These involved the building and collapse of a mountain to form a large, deep cavity having no surficial inlet or outlet. Evaporation, seepage and precipitation are in a perfect state of balance, allowing the maintenance of an almost static water level. Had any of

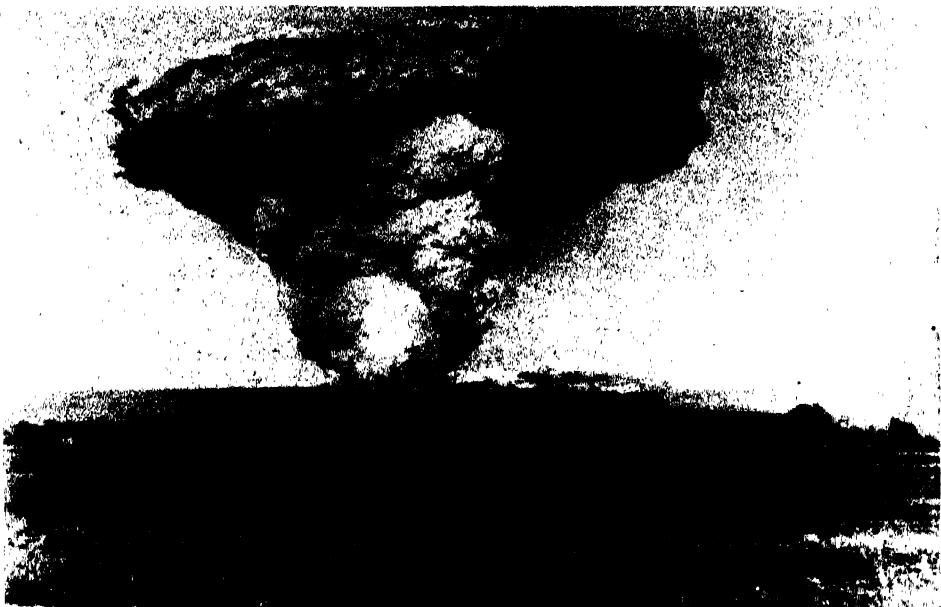
these conditions varied in slight degree, the lake might never have been formed. An analogous situation exists in the great Haleakala of Hawaii, which is also a collapsed crater. But here no deep lake fills the crater, and most of the bowl, 19 square miles in area, is arid.

Crater Lake has an area of 20 square miles, is six miles in diameter, 2,000 feet deep, and has a circular shore-line of 26 miles. The surrounding lava cliffs—the rim of the crater—rise from 500 to 2,000 feet above the water surface. The intense blueness of the deeper water, contrasted with the green of the shallower water around the margin, is recognized as the lake's most attractive scenic feature. This coloring is attributed to the scattering of light in water of unusual depth and clearness, just as the blueness of the sky results from light passing through the wide expanse of the atmosphere.

Crater Lake was discovered in 1853 by

a party in search of gold. In the gold rush excitement of those times, the existence of the lake was forgotten for many years. In 1862, and again in 1865, it was "rediscovered" by parties who each thought theirs was the initial discovery. Not until 1885 did the lake become generally known. Finally, in 1902, Congress established Crater Lake National Park.

Among the many volcanoes which burst forth along our Pacific coast during the closing days of the Tertiary Period, only one is still active to-day. This is Lassen Peak at the southern end of the Cascade Range in northern California. Here the volcanic activity has been so recent that there has been little time for modification of the mountain by erosion. Although Lassen Peak has been glaciated, the effects have been largely concealed by volcanic activity which continued after the close of the Pleistocene glacial epoch.



Loomis Photo, Courtesy National Park Service

THE GREAT ERUPTION OF LASSEN PEAK ON MAY 22, 1915
AS SEEN FROM A DISTANCE OF FIFTY MILES. THIS ENORMOUS CLOUD OF STEAM AND ASH ROSE TO A
HEIGHT OF FIVE MILES ABOVE THE CRATER.

The great volcano, rising to a height of 10,453 feet, has passed through two stages of growth. The earlier mountain was a broad, gently sloping mound of lava beds occupying a base from five to seven miles in diameter. Its successive lava strata rose to a height of about 8,500 feet. In the second stage, the present steep cone was built up on this previously established lava platform. This cone was formed of stiff, viscous lava which was forced up through the vent, piling up around the old crater in a dome-like mass. Movements and weathering caused huge blocks of the solidified material to break away from time to time, causing enormous rock slides which accumulated about the cone as the mountain was still growing. To-day this mantle of rock talus reaches almost to the summit.

A series of eruptions between the years 1914 and 1917 was the latest spectacular activity of Mount Lassen. The materials thrown out during the first year were not hot, most of them not even

melting the snows upon which they fell. However, on May 19, 1915, glowing lava spilled over the western rim of the crater, extending in a long tongue for 1,000 feet down the slope. On the northeastern slope much snow was melted, causing great mudflows which swept massive boulders weighing up to twenty tons into the valleys five miles away. A few days later, a terrific gas explosion shot dust and rock fragments down the northeast flank. The superheated blast destroyed or withered all vegetation for ten miles along its path. Simultaneously, a column of steam and ash rose to a height of five miles above the crater.

A final explosion occurred in June, 1917, after which the volcano again subsided into smoldering dormancy. Future eruptions may be expected, of course, but it is probable that the volcano is slowly dying—the last of a mighty chain of fire mountains that once blazed along our western shores.

Lassen Peak was originally designated a national monument by President Taft



Courtesy National Park Service

PERIODICALLY ERUPTIVE GREAT FIRE PIT OF HALEMAU MAU
AT TIMES IT BECOMES A CHURNING MASS OF WHITE-HOT LAVA, SHOOTING FOUNTAINS OF LIQUID FIRE
HIGH INTO THE AIR.



Pan-Pacific Press Photo, Courtesy Matson Navigation Co.

THE CRATER INTERIOR OF HALEAKALA IS LARGELY A DESERT WASTE UNLIKE MOUNT MAZAMA OF CRATER LAKE FAME. AT THE EXTREME LEFT MAY BE SEEN THE CRATER OF A SECONDARY VOLCANO, COMPARABLE IN ORIGIN TO THAT OF WIZARD ISLAND IN CRATER LAKE.

in 1906. Doubtless, there would have been no change in its status had not the eruptions of 1914-15 centered the eyes of the nation upon it. Consequently, in 1916, Congress established Lassen Volcanic National Park.

Truly active volcanoes, however, exist in our Hawaiian Islands. Most celebrated are Kilauea and Mauna Loa, which, together with dormant Haleakala, constitute Hawaii National Park, established in 1916. The great dome of Mauna Loa towers 13,680 feet above the waters of the Pacific, which is 16,000 feet deep at this point. The width of the mountain's base is unknown since it extends beyond the depths of exploration. But the volcano's total height, approximating 30,000 feet from base to peak, makes it actually one of the tallest mountains of the world. It is the largest active volcano, and has poured out more lava within the past century than any other in existence.

Kilauea seems to spring from the flank of monstrous Mauna Loa, but actually is a distinct volcano. Although only a little more than 4,000 feet in altitude, the crater of Kilauea is slightly larger than that of Mauna Loa.

Within the crater of Kilauea is the fire pit of Halemaumau, "The House of Everlasting Fire." Correctly translated, however, the name means "House of the Maumau Fern," a native species bearing leaves that are contorted and twisted like certain forms of lava. When active, this lava lake is one of the most spectacular demonstrations on earth. The white-hot glowing masses of lava sometimes subside to depths of a thousand feet, and again they boil upward to the rim, occasionally overflowing it. At times, roaring jets of lava shoot upward to heights of 150 to 200 feet.

Another section of Hawaii National Park contains dormant Haleakala, whose great crater, nearly eight miles in great-



Courtesy Union Pacific Railroad

NATURAL ARCHES AND WINDOWS

FORMED IN THE THIN WALLS OF BRYCE CANYON AT MANY POINTS. THE HARDER CAP ROCK REMAINS WHILE THE SOFTER ROCKS BELOW ARE FREQUENTLY ERODED AWAY.



Courtesy Union Pacific Railroad

EL GOBERNADOR

(THE GREAT WHITE THRONE) RISES 3,100 FEET ABOVE THE CANYON FLOOR OF ZION NATIONAL PARK. CARVED FROM MASSIVE SANDSTONE BY RUNNING WATER, THIS GREAT MONOLITH PRESENTS A DAZZLING SPECTACLE WITH ITS BRILLIANT RED BASE SURMOUNTED BY A GLISTENING WHITE DOME.

est diameter and 3,000 feet deep, is the fourth largest in the world. Only three known craters exceed it in size. One of these is in Japan, and two are in Italy. Haleakala, rising to 10,000 feet, was once much higher. But like Mount Mazama of Crater Lake fame, its great dome collapsed at some past time, and subsequent activity built up smaller cones within the great crater. With conditions of precipitation different, no great lake occupies the massive pit. Although some vegetation occupies the inner slopes, the vast crater is, for the most part, arid and barren.

The age of the Hawaiian volcanoes, from the time when they burst forth upon the floor of the Pacific, is not known. Geologically, however, they are quite young. In fact, Hawaii National Park, in point of geological age, might be considered as the infant of our great family of national park wonderlands.

THE CANYON PARKS

The magnitude of erosion by running water is nowhere more clearly visualized than in our great Southwest, where four national parks have been established. Nowhere else, in so limited an area, may be seen a greater sequence of the earth's stratified formations than are revealed upon the canyon walls of this vast region. Although many events of the world's history are not revealed in the formations of this region, at least some stages of each of the five great geologic eras have left their story here. From the Tertiary formations of Bryce Canyon to the ancient Archean granites at the bottom of the Grand Canyon, one may look backward through the reaches of time approximating, perhaps, a billion years of recorded earth history.

The four national parks of the Southwest—Bryce, Mesa Verde, Zion and Grand Canyon—may well be considered together because each represents a stage in a mighty geologic sequence. This sequence began when the Archean granites of this region were first flooded by the sea. Upon the floor of that sea were



Courtesy Santa Fe Railway

**STEP AND PLATFORM TOPOGRAPHY IN ERODED DEPTHS OF GRAND CANYON
CAUSED BY UNEQUAL HARDNESS OF THE ROCK LAYERS. THE ALMOST LEVEL HORIZON MARKS THE
SURFACE OF THE GREAT PLATEAU INTO WHICH THE DEEP CANYON HAS BEEN CARVED.**



Courtesy Santa Fe Railway

**PICTURESQUE APARTMENT HOUSES OF CLIFF DWELLERS
UTILIZING THE LEDGES, CARVED OUT BY RUNNING WATER, IN THE MASSIVE MESA VERDE SANDSTONE.**

deposited the Proterozoic sediments which were later crumpled and folded into a mighty mountain range. Those mountains are now missing, for they were worn low in the ages which followed. Their roots, however, are still visible where they rise as small hills on a rather level surface of granite in the lower parts of the Grand Canyon. All the horizontal layers which lie above these buried hills are sediments which were laid down when the seas again encroached upon the land during the Paleozoic Era, the third great division of geologic time.

The rim, or uppermost, stratum of the Grand Canyon continues northwardly across the plateau and becomes lost beneath the overlying formations of Zion National Park which were laid down during the early half of the next succeeding era, the Mesozoic. Following the latter formations eastwardly to Mesa Verde National Park, one encounters rocks of the later, or upper, part of the Mesozoic Era. Here they are capped by a massive sandstone layer which provided protection for the picturesque structures of the Cliff Dwellers. Continuing back westwardly again to Bryce Canyon National Park, one finds the Mesozoic strata topped by the Pink Cliffs, laid down during the Tertiary Period, or early part of the Cenozoic Era—the last of the five great geologic divisions. And above these, in the region, are recent lava flows. Thus, in progressing from the bottom of the Grand Canyon, through Zion and Mesa Verde, to the top of Bryce Canyon, one passes through a greater sequence of geologic formations than in any other known area of equal extent.

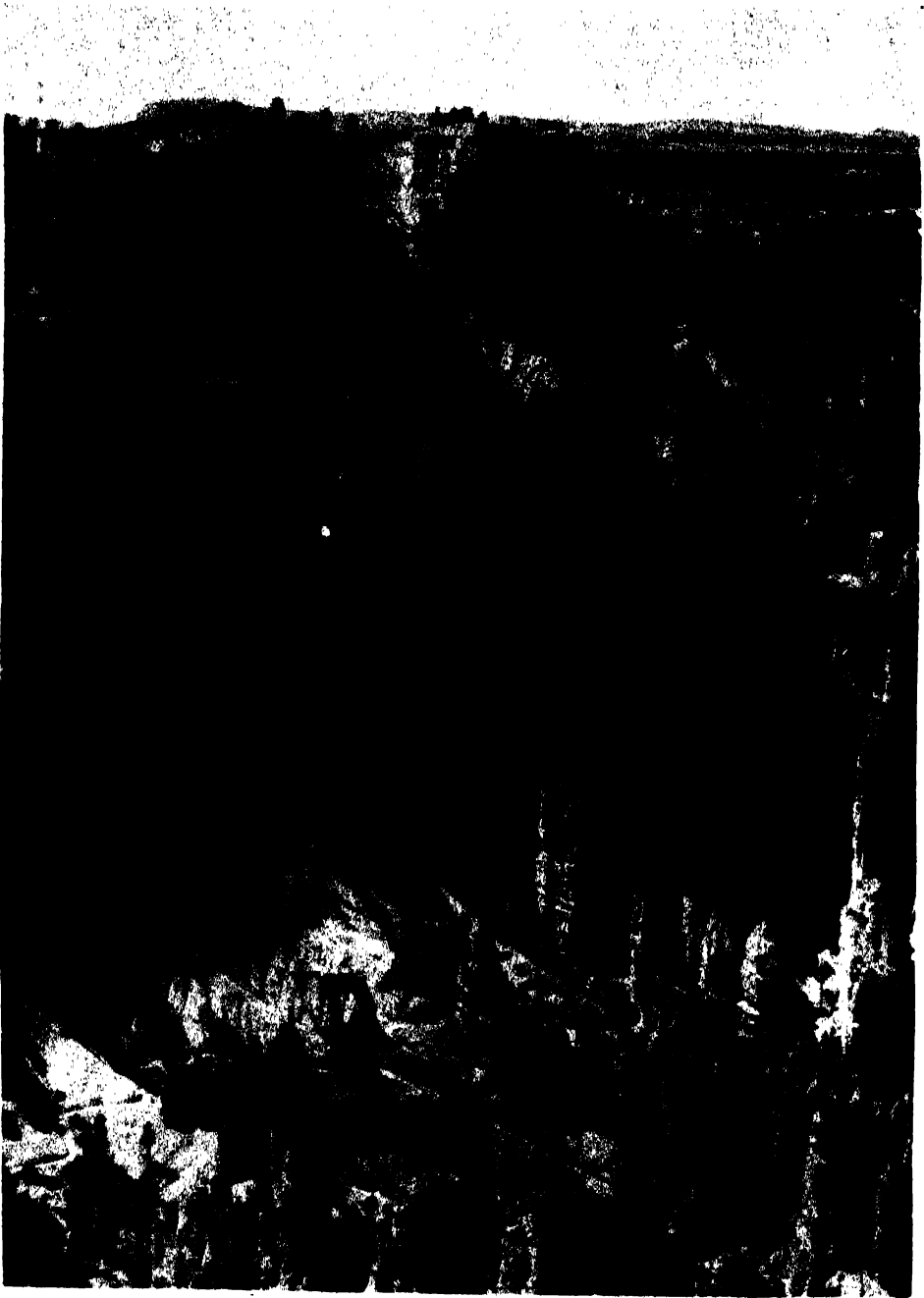
The latest elevation of this great plateau region is thought to have taken place at the close of the Tertiary Period, just prior to the beginning of the Great Ice Age. The cutting of the Grand Canyon to a depth of a mile in this plateau, as well as that of the other canyons, was

accomplished entirely by running water; ice played no direct part in this erosion. This cutting represents only a comparatively short duration of time in comparison to that required for the deposition of the strata themselves.

The Grand Canyon of Arizona has become the most famous canyon in the world. It is not, of course, the deepest known valley, nor quite the deepest canyon; but the combination of depth, length, width, steep-sidedness and coloring causes it to excel all others. In places there are sheer drops of 2,000 to 3,000 feet; elsewhere the canyon walls retreat in regular fashion, step by step, from the inner gorge to the rim. The various strata forming these steps vary in hardness, and hence, in their resistance to erosion. Each resistant bed stands out like a cliff, and each intermediate weaker bed is faced with a slope. The rim of the canyon is composed of the hard, massive Kaibab Limestone which extends for many miles in all directions.

The Colorado River, as viewed from the rim of the Grand Canyon, appears quite insignificant. Actually, it is one of the great rivers of the world and the second longest in the United States. At the gaging station in the canyon, the river is 300 feet wide, its flow ranges from $2\frac{1}{2}$ to 20 miles per hour, and its normal depth varies from 12 to 42 feet. The river is subject to sudden floods, with the volume multiplying several times in a single day, and the level rising accordingly.

The suddenness with which the river drops—14,000 feet from its source in the mountains of Colorado and Wyoming to its mouth—gives it enormous eroding power. Measurements show that about 1,000,000 tons of sand and silt are carried past the gaging station every 24 hours. Because of the aridity of the region, plants grow sparsely upon the slopes, providing little protective cover.



Courtesy Union Pacific Railroad
SANDSTONE FORMATIONS IN BRYCE CANYON NATIONAL PARK
THESE GROTESQUE SHAPES ARE THE RESULT OF EROSION UPON STRATA OF UNEQUAL HARDNESS.

Hence, spasmodic showers concentrate more energy here during a single torrent than might be realized during a full season's rainfall in a region of denser vegetation. For the same reason, the tributary streams are largely intermittent. The great elevation of the plateau, however, enables them to cut deeply during every infrequent storm so that the results of their cutting are gigantic in scale.

The carving of Zion Canyon by the Mukuntuweap River, a tributary of the Colorado, is essentially the same, except on a smaller scale. Bryce Canyon, however, is a great horseshoe-shaped amphitheater, or box canyon, three miles long and two miles wide. The rocks of Zion and Bryce canyons are among the most colorful of any which make up the earth's surface. They range from almost pure white to chocolate, with numerous intermediate shades of yellow, orange, pink and red. Dominant, however, is the

pale rosy pink of the famous Pink Cliffs of Bryce Canyon.

Mesa Verde National Park is not, in itself, a single large canyon. It is rather a great plateau which has been partially dissected by numerous steep-sided valleys and canyons cutting into it in finger-like fashion. The small, intermittent streams which have cut these valleys are tributaries of the Mancos River, which, in turn, is a tributary of the Colorado. In working headwardly into the mesa, the streams have dug out narrow platforms and hollows along the faces of the sandstone cliffs. These were utilized by the Cliff Dwellers as sites for the construction of their dwellings. Interest in Mesa Verde is centered primarily in these cliff dwellings, which are among the finest known examples of their kind; yet one should not fail to appreciate that it was erosion which produced the sites for these unique structures.

(To be continued)

SCIENCE VERSUS LIFE

Now, I shall try to say in one minute what I probably failed to make clear in fifty. As I see it, ours is not an age of science. Men are still driven by greed and confused by guile, rather than guided by reason and justice based on our expanding knowledge. Science has greatly enlarged man's understanding, conquered many of his diseases, lengthened his life, multiplied his joys, decreased his fears, and added much to his physical comforts and powers. But man may use these and other achievements for a greater social injury, instead of for a further social advance. Science is specifically human, in that it stems from the innate curiosity of all men, and the conspicuously plastic brains of the ablest, if not the noblest, of our fellows. If this be so, it follows that the scientific method and its products can not be, in any fundamental and permanent sense, in conflict with human nature, though our present human society, product of a past dominated by greed, force and fear, may be, and is in conflict with the scientific method. Whether science and the scientific method, whether understanding, honesty, reason and justice can contrive survival values equal, if not superior to the blind forces of nature which shaped man's past, is as yet in the laps of the gods. Still, we can not deny the possibility, and

we *will* nurse the hope, that the hairy ape who somehow lost his tail, grew a brain worth having, built speech and song out of a hiss and a roar, and stepped out of the cave to explore and master the universe, may some day conquer his own irrational and myopic behavior towards his kin.

I think we can say, even in the face of current pessimism, that during the ups and downs of past ages man has gradually acquired more understanding, more freedom from fear, more dignity, greater kindness and a clearer conception of justice. Even though for the moment, "the bird of sorrow" is not only flying over our heads, but is actually nesting in our hair—to borrow a Chinese proverb—that bird will not nest in our hair forever, even though a blackout on the light of science is decreed in every land. For slowly, but surely, the method of science will help to make life more intelligent, toil more cheerful, fear and hatred, pain and tears less prevalent in our lives. If in any place or time the blind fury of hatred of our brethren and the insane violence of war render the pursuit of science impossible, and the scientific method submerged and forgotten, it will be rediscovered, in better days, by better men.—A. J. Carlson, *Sigma Xi Quarterly*, Vol. 28, No. 4, 1940.

ZOOLOGICAL GARDENS. II

By Dr. ETHAN ALLEN ANDREWS

EMERITUS PROFESSOR OF ZOOLOGY, THE JOHNS HOPKINS UNIVERSITY

WHILE France developed its one chief zoological garden from the Jardin des Plantes, the earliest beginning (except one) of any in Europe, Germany gradually made several zoological gardens continuing on from more or less ancient beginnings.

In 1812, Frederick, the first king of Württemberg, ordered a zoological garden near Stuttgart where already in keeping there, animals could be found about his royal pleasure house, in appropriate housing, and in 1814 the buildings were finished and contained 54 apes, three elephants, a tapir, a leopard, five bears, six buffalos, two quaggas, two beavers, two kangaroos, three armadillos, and 40 parrots, eagles, ostriches and other birds. But when Frederick died in 1816, his son, William, ordered the menagerie to be sold, since famine due to crop failure had fallen heavily upon his people. During more than a year the sale of animals continued and some were bought up by the king of Bavaria and the Grand Duke of Baden, thus strengthening various zoological collections in Germany.

This dispersion of wild animals led to a memorable contest between man and beast wherein intelligence and force were not distributed to the great credit of man, for when the big elephant weighing 4,622 pounds was sold to the owner of a menagerie in Berlin for 3,300 florins, and was to be shipped to Venice on a coasting vessel, the bending of the gang plank made the beast hesitate about going on board at all. Repeated offers of food held out to tempt him to board so greatly excited the elephant that he desperately assaulted and killed his keeper and made a raid on the

fruit stands. The military fired a salvo into the elephant, who thereupon ran down a blind alley, broke into a house and tried to climb the stairway until it broke under his weight. Repeated shootings collapsed the great beast, but he rose again and broke into the door of the Church of San Antonio on the bank of the Riva near Schiavoni, and in this sanctuary made some sort of defense by collecting benches about himself.

The end of this farcical tragedy was that on the next day the brave soldiers brought up a cannon and having made a hole in the wall of the church, fired a cannon ball into the body of the elephant. Its skeleton and skin went to the collection at Padua.

One of the first and greatest zoological gardens of Germany, that at Berlin, the third oldest in Europe, was preceded by the Jagerhof, founded in 1725 and containing aurochs, bears, elks, seals, falcons, etc., and also by the menageries on Peacock Island, near Potsdam, where were kept monkeys, kangaroos, llamas, bears, wild swine, beavers, eagles and so on.

To build up a great zoological garden was the plan conceived by the traveler and zoologist, M. H. K. Lichtenstein, and this was to be located in the pheasantry at Charlottenburg. So he spoke to Baron Alexander von Humboldt and the latter laid the matter before the king. The king allowed the breaking up of his pheasantry and the donation of 407 animals that were then on the Island of Peacocks. Lichtenstein then formed "The Society of the Zoological Gardens of Berlin," and to this the state contributed \$1,500 for five years without interest, but later at three per cent., and

subsequently the sum was raised to \$25,000. The garden was carefully laid out in advance by the general director, Lenné, and the buildings were designed by Professor Strach and the architect, Cantian. It was opened to the public on August 1, 1884. At first Humboldt was on the commission that held control.

Growth at first was very slow; by 1868 the public had taken up only 191 shares at \$75 each. And after the death of Lichtenstein in 1857, a period of stagnation set in until the new director, Dr. Bodinus, formerly director of the zoo at Cologne, set the great Berlin zoo on its feet permanently. In 1870 there were in this zoo more than 250 mammals, and 760 birds of 350 species, all estimated to be worth \$40,500.

Successive directors were attracted from the zoological gardens at Frankfurt and at Cologne. In 1900 the society placed the administrative work

in the hands of one director, and the scientific work in the hands of a separate director. By 1907 this society enrolled 3,000 members and employed 115 persons in the garden. With some slight aid from the city they raised by entrance fees, and so on, \$200,000 for annual expenses, and at that date the garden contained 3,149 animals belonging to 1,297 species.

In this Berlin garden was invented the plan to have the buildings characteristic of the countries in which the animals naturally lived, a scheme often difficult to execute without great detriment to the real value of the animals, which tend to be subordinated to gaudy and bizarre styles of architecture.

With concerts and other side attractions, there grew up one of the largest and most useful popular zoological gardens of Europe. Directors with much experience were drawn hither from



OSTRICHES ACCUSTOMED TO BEING KEPT OUTDOORS IN THE SNOW BY CARL HAGENBECK AT STELLINGEN IN NORTH GERMANY. HAGENBECK IS APPRAISED BY PEEL AS "THE MOST OBSERVING, MOST SUCCESSFUL KEEPER OF LIVE ANIMALS IN THE WORLD." HE FOUND THAT MANY TROPICAL ANIMALS WOULD THRIVE IN HIS MOST ASTOUNDING ZOOLOGICAL PARK, IF GIVEN PROPER FOOD AND EXERCISE, FOR "THEY MUST HAVE FRESH AIR ALL THE YEAR ROUND."



SOME OF THE THIRTY-TWO HEAD OF EUROPEAN WILD BISON
AS SEEN IN 1907 IN THE VAST DOMAIN OF THOUSANDS OF ACRES IN UPPER SILESIA OWNED BY THE
DUKE OF PLESS, DERIVED FROM ANIMALS BROUGHT IN 1865 FROM RUSSIAN POLAND.

other gardens. Dr. Heck increased the number of animals to 25,000, of 12,000 species.

In 1898 new shares were issued, bringing up the capital of the company to more than one-half million dollars and with statuary and all sorts of buildings and diversions added to the sight of the scientifically arranged animals, the people thronged to the garden to the number of 60,000 on a fine Sunday.

This great development was based upon two factors: the great love of the people for animals, and the interest of the Emperor of Germany—history repeating somewhat of the old menagerie of the City of Assur with, however, a very great advance made in the share due to the people.

A second zoological garden in Germany, at Frankfort, arose in 1857 when, after much discussion, a committee of eight men obtained from the Senate a law to establish a zoological garden with

a capital of 50,000 florins in 200 shares of 250 each, non-taxable, members and families to have free admission. On the Bochenheimer pike 14 acres were rented for 10 years.

The next year the capital was doubled and all the shares were taken up before the opening on August 8, 1858. The membership increased: 1,052 in 1858; 1,382 the following year, most of the holders being families. Although at first there was not only a director in charge of the animals, but a scientific head, who started a publication, *The Zoological Garden*, in 1859, which was continued on into 1866, it was found that there was not much popular appreciation of the scientific side of the garden and so this aspect was discontinued for a time but is now in its third series.

The non-scientific point of view seems well shown in the emphasis at first put on the agreeableness of the exhibits to the senses; thus at first the carnivora

were excluded, for it was said in the prospectus that wild and flesh-eating animals could not be kept in a garden except in cages and belonged rather to a menagerie than to a garden; and moreover, such animals are of little interest, as being generally afraid of light they are asleep or hidden away by day and they generally assail the nerves of smell. How different are the possibilities to-day since the introduction of moated enclosures in the most progressive gardens! Nevertheless, this same appreciation of the esthetic in the zoological garden is one of its most commendable virtues to be duly cultivated and at a later date, 1903, this same garden was noted as one of the prettiest in Europe with its lawns, big shady trees, ponds and flowers.

Soon, however, the gifts of carnivora by people of Frankfort who had gone abroad led to the adoption of the usual classes of animals in this zoo, and the garden flourished materially. From 1858 to the end of 1883 the garden recorded 1,276,004 people visiting it.

After the wars, a new lease of life was given to the garden when, in 1872, a new Zoological Society was formed with a capital of 1,300,000 florins to accept the offer of the city of 37 acres in the Pfingstweide free for ten years, and then at an annual rental of 10 florins per acre.

The first tree was planted on the new site on March 24, 1873, and the old animals transported so that at the end of that year the garden contained 1,108 animals of 260 species, valued at 46,360 florins.

In a few years an aquarium was added. In 1900 the income had grown to more than \$50,000; in 1905, to \$64,000; and in 1906, about \$80,000; and it occupied seventeen and a half acres with most carefully tended paths, lawns, flower beds, with many fine animal houses in which the animals thrived and bred, while especial attention was given to the many fine bird collections, both native

and foreign. Strange to say, the garden possessed a remarkable collection of butterflies, about 25,000 specimens, in 1903. In 1905 they were keeping alive some 3,000 butterflies in the chrysalid state in the expectation that when they transformed into adults the people would enjoy the sight of many beautiful butterflies from India, South America and Africa—certainly a unique exhibit! In 1906 about 3,000 animals were in this garden.

In this Frankfort garden could also be observed on the wall the record of the increasing annual measurements of the African elephant from 1901 to 1906, 1.160 to 2.235 meters, recalling the old homesteads wherein like wall marks recorded the growth of children!

But in addition to these great gardens of Berlin, Frankfort and Cologne, already spoken of, others arose in Germany of various degrees of importance. Some we will merely enumerate, as at Breslau, Hamburg, Stellingen, Konigsberg, Stuttgart, Aix-la-Chapelle, Elberfeld, Duesseldorf, Muenster, Hanover, Leipzig, Dresden, Posen, Augsburg, Karlsruhe, Mülhausen, Nymphenburg, Halle, Heidelberg and even more.

ZOOS IN THE NETHERLANDS

Along with the activity shown in Germany and France there were developments of zoological gardens in other parts of Europe and in England.

In Holland the painters of the seventeenth century were able to portray animals in Paradise and in pictures of Orpheus in a much more realistic way than was possible in Italy, since in Holland the animals of foreign lands had become better known through extensive trading with America, Africa and Asia. As early as 1784, a 3,000 pound rhinoceros was sent from Bengal to Amsterdam. And in that period came the ending of a much loved inn, in Amsterdam, "*zum blauen Tau*," connected with

which there was a menagerie of importance.

Near The Hague in a castle, "*het Loo*," the hereditary ruler maintained a collection of curiosities and a menagerie, and the director in 1766-1784 published a list, with illustrations, of 31 remarkable animals brought from the colonies to this menagerie. This catalogue was translated into French by Renfer in 1767-1787, and again later published in Dutch in 1804.

It is related by Houel, in a history of the two elephants of Paris, that at the time of the French invasion, 1795, when the Dutch ruler was driven out, the animals at the Loo were carried off and added to the collections of the *Jardin des Plantes*.

In 1809, King Louis, of the house of Bonaparte, established a zoological menagerie that continued only thirteen months and then, on dissolution of the Kingdom of Holland, was sold at auction. Twenty years after this, upon the restoration of the monarchy under the House of Orange in 1835, an attempt was made to start a government zoological garden after the pattern of the great Zoo of London. The book dealer, G. F. Westerman, was the active agent in this movement. But it was not until 1838, on the founding of the society, "*Natura artis magistra*," that land was bought and the zoological garden opened in Amsterdam. In 1840 the famous zoological menagerie of Aken was purchased and added to the Amsterdam zoo, and Westerman was made the director in 1841. Since 1852 the society has been called "The Royal Zoological Society," and since 1847 it has published the scientific journal, "*Beitragen tot de Dierkunde*."

Rotterdam also developed its zoological garden, and there were gardens in Antwerp, Brussels, Ghent and Liège, while others sprang up in all parts of Europe, as at Madrid, Basle, Buda-

Pesth, Copenhagen, Moscow and at St. Petersburg and Rome.

Something of the sequence in founding these various gardens will appear later, but we must not overlook such activities in the British Isles and the great collections in the zoo near London.

BRITISH ZOOLOGICAL GARDENS

The first zoological garden, in the strict sense of the term, developed from the so-called Knowsley menagerie of the Earl of Derby at Knowsley, England. Its elephant folio, for private circulation, is entitled "Gleanings from the Menagerie and Aviary at Knowsley Hall. Hoofed Quadrupeds. Knowsley 1830, with 59 plates painted, or else printed, in colors, lithographed with notes by the Earl of Derby, and published by John Edward Gray."

On the death of the earl this collection of animals formed the basis for the Regent's Park Zoo, the great real "zoological park" of the Zoological Society of London. This famous society began in 1826 at the suggestion of the president of the Royal Society, Sir Humphry Davy (who died in 1829), and the geographer, Stamford Raffles (who died in 1826). The objects were to advance zoology, and to introduce into England new and remarkable animals. It thought to establish a museum of stuffed animals and a permanent menagerie in which should be kept all foreign birds, mammals and fish that could possibly be tamed.

This idea met with approval. In 1829 the members of the society paid fees to the amount of more than \$8,000 and rented from the Crown some thirty-one acres in Regent's Park. They placed the animals partly in houses and partly in the open, and first applied the term, Zoological Garden. These collections and the numerous publications arising as the scientific work of the society furnished the starting point for a great advance in zoology in England. In ten

years after the beginning, the society had 3,011 members, each paying \$15 yearly, and an initiation fee of \$25. The garden contained some 1,000 different sorts of mammals and birds. Non-members paid a shilling a visit, and this made a revenue of \$30,000, the entire revenue being \$75,000.

By 1905 this garden of a great society contained nearly 3,000 kinds of vertebrate animals. By the year 1923 the

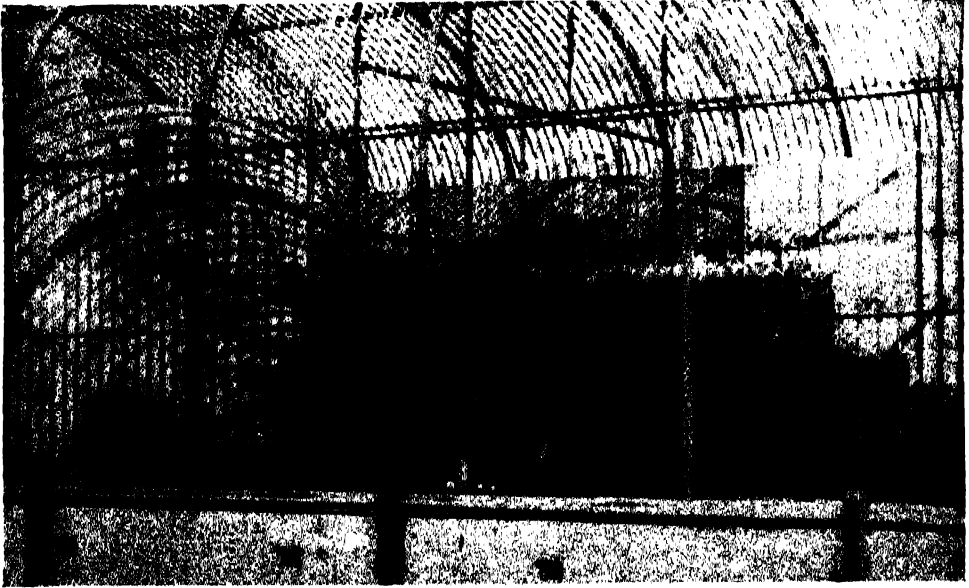
number had become more than three thousand.

Between five and six thousand members of the Zoological Society of London paying \$80,000 fees, with \$250,000 admission fees, brought the total income up to well toward a half million dollars, and left a surplus of some \$60,000.

The more recent expansion of the London Zoo over a large area of countryside in which man, the visitor, is, as it



THE COLLECTION IN PRINCELY PARK, "HET LOO," IN HOLLAND
IN TIME OF WILLIAM III, MIDDLE OF THE 18TH CENTURY, AS PAINTED BY MELCHIOR D'HONDECOETER.



LIONS AS SEEN BUT POORLY EVEN IN THE BEST OF IRON CAGES
FROM THE 1939 REPORT OF THE ZOOLOGICAL SOCIETY OF VICTORIA, AUSTRALIA.

were, the enclosed creature and the animals more free to roam, is worthy of all praise and emulation. Although this zoo is so large and the isles so small, there are other zoos, as at Woburn and Manchester, Dudley, Bristol (Clifton), Paignton, as well as the aquaria in Brighton, Stibbington Hall, Blackpool, Liverpool and London.

Our history shows these modern animal gardens grew out of the ancient menageries that were chiefly for the enjoyment of the wealthy overlords, but gradually grew to be shared more and more with the common people, until finally they were given up exclusively to the populace for enjoyment and education.

But Europe had other uses for strange animals and one of importance was a more or less serious attempt to try out the possible practical gains to be had by taming wild animals to add to the comparatively few domesticated animals we have inherited from antiquity with, alas, so very few additions. Acclimatization

and utilization of exotic animals seem most worthy of encouragement when we consider the virtues of many beasts and fowls that are in danger of extinction.

The European parks for acclimatization were essentially zoological gardens hoping to add to the nation's wealth rather than merely to the people's pleasure.

PARKS FOR ACCLIMATIZATION

Along with the various menageries and parks that may be called zoological gardens, there have arisen a few similar institutions whose chief objects have been to see how far it may be possible to introduce exotic animals and make them of use as domestic animals.

The first in point of time was the unsuccessful attempt to domesticate the dromedary at San Rossore, an hour from Pisa. Here the dromedary was domesticated on a farm with fine pine forests founded by the Medicini, probably under the Grand Duke Ferdinand II. of Tuscany, 1621-1670. In the first report in 1690, it is stated that six pairs had

been brought from Tunis, but only seven animals remained. In 1738 and 1739 seven more pairs were brought from Tunis by the Grank Duke Francis II. In 1784 there were as many as 170 dromedaries, and in 1789, 196. More than \$300,000 were spent in purchasing dromedaries at Livorno and three men of Tunis were employed in caring for them.

According to an account published by the Swedish consul at Livorno in 1840, these dromedaries had free range over twenty miles of land, stockaded on one side, and bounded by rivers and the sea elsewhere.

Divided into workers, breeding females and foals, they were herded morning and evening by mounted guards. Most of the year they sought out their own food, but the breeding females were fed hay in huts, in December. The females continued to breed up to the age of twenty-one years and some lived here as much as thirty years. The young males were put with the working animals and, being tied, fed and cleaned by men became tamed and then broken to saddle and taught to kneel down. From November to May the workers were kept in stalls; they drank but once a day and ate half the food and did double the work of horses, which were not well adapted to the loose, sandy soil; while the camels, led in groups of three by one man, carried much building material and agricultural apparatus.

In 1840 the animals numbered 171, 91 male and 80 female, of which one was a breeding male, 58 breeding cows, 66 workers, 39 foals and seven young calves.

Here may be mentioned the domestication attempts in Australia, where the camel was of use in opening up the dry interior country.

This idea first arose in the London Geographical Society in 1844, when in the presidential address of Sir Robert Murchison the need of the camel to make

possible the penetration into the interior was mentioned, and in the explorations of Sir Horrocks in 1846 one camel was taken, but it was not until 1860 that they were used in numbers in the expedition of Burke from Melbourne to the Gulf of Carpentaria, the Government of Victoria buying 25 camels from India for \$25,000. The following year one of these camels was used by Mackinley in searching for Burke's party. Thomas Elder, one of the richest landowners in South Australia, sent to India in 1866 and successfully imported 121 out of a shipment of 124 camels, along with a dozen African grooms. It was found that the camels reached high and flourished on vegetation the horses and cattle could not get at, and thrived upon all sorts of green plants, although they were made sick by some plants, especially *Gyrostemon romulosus*.

At ten years the young was like a four-year-old, and could be used thirty years or more. Moreover, the usual whipping the colonists bestowed on oxen had to give place to kind treatment, since the furious camel may attack, bite and kneel upon the brutal driver.

The working powers of the camels from Kandahar, brought in by Elder, were marvelous. Laden with 600 pounds of wool they went sixteen to seventeen miles a day, and four to five days without water, learning by experience to store up water, after practice. One carried an Afghan and the mail 350 miles in a week, while the riding camels of Mekron may run seven to eight miles per hour.

While there have been other gardens of acclimatization such as those near Cairo in Egypt described in the *Heimat* of Vienna, 1879, these are too remote from the present consideration of zoological gardens, and we turn back to the garden of acclimatization at Paris, which proved to be a veritable zoological garden, and something more.



COLLECTING WILD ANIMALS FOR ZOOS

THE ARTIST IN "BEASTS AND MEN" THUS CONCEIVES THE EFFECT UPON WILD ANIMALS OF THE COMING OF THE COLLECTOR.

This most famous of acclimatization gardens is the rival of the Jardin des Plantes in Paris, with which it has much history in common, for we find that the then director of the Jardin des Plantes, in 1854, Geoffrey St. Hilaire, in order to introduce into France, and Europe in general, new animals and plants that

might prove useful, founded a society. In 1858 this developed as the *Société du Jardin d'acclimatation*, with a capital of \$200,000 in shares of \$250 each, which rented some fifty to sixty acres of the Bois de Boulogne from the City of Paris at an annual rental of \$200.

With the aid of the city architect and

the advice of the secretary of the Zoological Society of London, the plans matured rapidly so that the garden opened in 1860 with very much the aspect of a zoological garden, large meadows alternating with woods and shrubbery, streams, pools and waterfalls with artistically laid out roads and paths.

As this garden, in a sense, took the place of the old garden of the King that the Commune had destroyed, it was thought wise to introduce into it very much not at all bearing upon the problems of domestication, and thus it developed as a large zoological garden in which, however, some of the animals had a practical use not anticipated, for when the siege of Paris was imminent, although many animals were shipped to the zoological gardens at Brussels, Antwerp and Tours as quickly as possible until the stoppage of trains put an end to this salvage, there remained in Paris some animals which were taken over by the Jardin des Plantes and the garden itself, being outside the fortifications, suffered but little. The animals, however, in the Jardin des Plantes were consumed as food and thus made useful.

After that the expatriated animals were brought back, only to suffer at the hands of insurrectionists, who made the garden a battleground and wounded both man and beast.

However, the garden of acclimatization recovered, receiving \$7,000 from the society and \$12,000 a year from the City of Paris for three years, and a gift of two African elephants ("Romeo and Juliet") from the king of Italy and other animals from the gardens of England, Antwerp and Brussels.

In addition to the cages and parks for the regular zoological park inmates, there are, in addition, many things that are of note. There was a project to supply pure milk at various depots in Paris; a department for the fattening of poultry; a library of natural history with lectures and conferences. Concerts, too, made the garden popular. With a fine palm-house, there was also a special building for the breeding of various species of silkworms, *Bombyx mori*, *Bombyx cynthia* and *Attacus pernyi*. Opportunities were offered the public to ride on 30 kinds of ponies from Java, Ireland, Scotland, Spain and Siam, or on horses, camels, elephants and zebras; or to be pulled about in wagons drawn by ostriches. There were: a lecture hall seating 8,000; a monkey hospital; an aquarium; a place for sale for many vegetables and plants; the most beautiful and complete collection of vines in the world; a bee house; experimental gardens; dog kennels; a hall of ninety feet displaying agricultural apparatus for sale; hunting and fishing collections;



Courtesy The National Zoological Park, 1941
 GIRAFFES APPEARING AS IF IN THEIR NATIVE AFRICAN RANGE
 IN THE NATIONAL ZOOLOGICAL PARK, WASHINGTON, D. C.



Courtesy of the New York Zoological Society

DEER RANGE IN THE BRONX ZOOLOGICAL PARK, NEW YORK

SHOWING THAT THE PHOTOGRAPHIC LENS TO-DAY APPLIED TO MODERN MODES OF KEEPING WILD ANIMALS MAY VIE WITH THE SKILL OF PENCIL OR BRUSH IN ARTISTIC REPRESENTATIONS OF ANIMAL LIFE.

a pheasantry; many kinds of sheep; a daily exhibition of the catching of fish by Chinese cormorants; the largest collection of kinds of pigeons ever brought together; many sorts of poultry and eggs for sale; carrier pigeons descended from those that carried 115,000 messages during the siege of Paris; a meteorological observatory; horse stables; riding school; horse breaking; a free gymnasium for children; fish hatcheries; a library of zoological and agricultural books, as well as Parisian papers and periodicals; concerts; restaurant; dogs, rabbits and all sorts of birds for sale—what else need one add to this cyclopedic Zoological Garden!

This, however, is not the whole, for there are other parts of France that aid in the general plan, and at Marseilles the extensive zoo is a sort of half-way house for animals on the way from Africa to Paris.

Although in Washington much has been done by Fairchild and others in finding and introducing foreign plants, not so much has been accomplished for animals. Consider what might have been added to our farmyards had the sailors not eaten up the Dodo—and how useful the “passenger pigeon” might have been if not exterminated. Possibly before they themselves are exterminated, men of wealth may be found to save the manatee (the mermaid of Florida waters) and the pigmy hippopotamus that might both help clear obstructed rivers and furnish both meat flesh and the inner organs some dietitians say may be so needed by man!

ZOOLOGICAL GARDENS IN INDIA

During the centuries of progress in Europe, India had also advanced in its zoological collections, but here some of the old-day domination of princes ling-

ers on in company with the growing support of city and public zoological collections. In India we find an overlapping of the more primitive stage comparable with that of Assyria and Egypt and the more modern phase that is best expressed in the United States, where the people take the place of the prince as owners of the zoos.

In 1913, when Flower studied the collections of India, there were twelve public gardens and as many more to which the public had some access; however, these latter were chiefly private collections and special stables and places for the keeping of elephants, crocodiles, etc.

Of the twelve, three belonged to the Maharajas of Baroda, Jaipur and Mysore; five to the governments of Bangalore, Calcutta, Lahore, Rangoon and Trivandrum; and four to the cities of Bombay, Karaichi, Madras and Peshawar.

Most of them were free to all who wished to visit them, and almost all of them exhibited mammals, birds and reptiles. They were established from 1855 to 1909. The largest, at Alipore, Calcutta, founded in 1877, contained 339 mammals of 126 species, 194 species of birds and 41 species of reptiles.

ZOOLOGICAL GARDENS IN NORTH ASIA, AFRICA AND AUSTRALIA

The modern vogue for zoological parks has left old Asia cold—great China seems not yet to have taken it up. In Japan, however, in 1900, the people started a movement to celebrate the royal wedding and raised funds which were presented to the City of Kyoto for a zoological garden to be controlled by that city. By 1923 this establishment was visited by 866,825 people, and its receipts were 10 per cent. in excess of expenses.

Africa, the great natural zoological

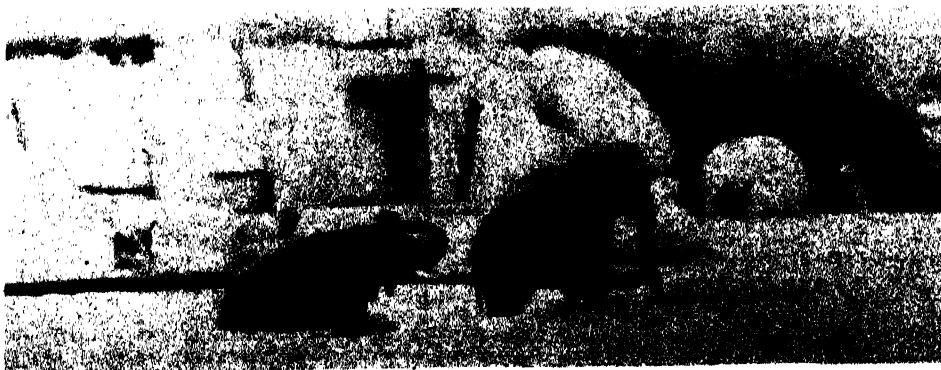


Courtesy of the National Zoological Park, 1941

**PENGUINS BEHIND DOUBLE GLASS IN AN ARTIFICIALLY COOLED ROOM
IN THE UNITED STATES NATIONAL ZOOLOGICAL PARK, WASHINGTON, D. C.**



NEW BARLESS ENCLOSURE FOR POLAR BEARS IN THE PITTSBURGH ZOOLOGICAL PARK



**AFRICAN AND INDIAN ELEPHANT LIVING PEACEFULLY TOGETHER
IN THE DETROIT ZOOLOGICAL PARK IN A MODERN ENCLOSURE NOT BARRED FROM THE PUBLIC; MANY
PARKS SHOW "HAPPY FAMILIES" OF DIFFERENT ANIMALS LIVING TOGETHER.**

garden with its valuable reservations for safeguarding some of the native animals, is still a great supply house for menageries the world over, a center of supply being the Egyptian province of Taka, whence animals start for the important London market. In this business of supplying the menageries of the world, Ger-

many took the lead with such men as Carl Jamrach, Hagenbach and Reiche.

The value of the animals taken in Africa becomes very much enhanced by the great costs of transportation; thus an elephant worth \$20-\$100 becomes, in Europe, worth \$700-\$1,500; a giraffe that costs \$20-\$50 is there worth \$500-



Courtesy of the St. Louis Zoological Park, 1941

ELAND ANTELOPES IN THE ST. LOUIS ZOO

**FREE IN LARGE MOATED RANGE BUT WITH AN INNER RETREAT BEHIND ARTIFICIAL BOULDERS MADE
IN IMITATION OF THOSE OCCURRING NINETY MILES AWAY. HERE THE VISITOR MAY ENTER RETREAT
TO SEE ELANDS INDOORS.**



MONKEY ISLANDS IN TULSA ZOOLOGICAL PARK, OKLAHOMA

180 BY 130 FEET, EMBRACED BY THIRTY FEET OF WATER. NO LONGER DO MONKEYS NEED TO BE CONFINED IN CAGES RESTRICTED BY BARS, BUT FROM AUSTRALIA TO FAR PARTS OF THE UNITED STATES THERE ARE MANY FINE HARLENS ENCLOSURES WHERE MONKEYS AND BABOONS CAN GET SUNSHINE, EXERCISE AND FREEDOM FROM HUMAN ANNOYANCES.

\$700; a rhinoceros rises from \$40-\$100 to \$1,500-\$3,000; and a young lion goes up from \$2-\$5 to \$150-\$600.

But not all African animals are thus sold out of their native land; some are kept in zoological parks such as those at Giza, near Cairo, at Khartoum and at Pretoria.

Even Australia, the smallest continent and the latest to be highly civilized, has its zoological gardens; and thus, finally, carnivora gain access to this isolated land where they were so long absent that the dominant mammals, "marsupials," there took on the habits of carnivores and herbivores, as if in imitation of what was proper in the rest of the world. Australia has very much up to date zoological gardens at Melbourne, Adelaide, Sydney and Perth.

At Sydney, the bears, lions and tigers are kept in moated enclosures, and for the last there are moats eighteen feet deep and twenty-five feet wide. Maintained by the Taranga Zoological Park Trust, this park contained, in 1916, 189 mammals of 84 species, 450 birds of 103 species and 63 reptiles of 13 species.

Even New Zealand has its zoological park, at Wellington, and thus the future New Zealander can get the needed education before visiting the British Lion and seating himself upon London Bridge!

ZOOLOGICAL GARDENS IN THE AMERICAS

The long vanished menageries of the natives have been reincarnated in the many zoological gardens of all the Americas.

In South America, a fine zoological garden arose at Buenos Aires, and another at Para, Brazil; while smaller ones sprang up at Bahia and at Rio de Janeiro and at Blumenau, Brazil.

Far to the north, Canada had its zoos at Toronto, Sault Montmorency, Quebec and Winnipeg.

In the United States, the mature and relatively old city of Philadelphia started a zoo to be like that of London, and later New York had its Central Park Zoo and the great garden of the Bronx, with its remarkable rivals at St. Louis and the National Gardens in Washington. But at various times and places zoos of many grades have come into existence through the breadth, if not the length, of the land—as at Chicago, San Francisco, Cincinnati, Buffalo, Milwaukee, Prospect Park in Brooklyn, Baltimore, Denver, Detroit, New Bedford and Springfield in Massachusetts, Pittsburgh, Boston, San Diego and others.

If we now glance at a list of zoological gardens and the dates of their beginnings, we see that after the long disappearance of the menageries and zoos of

antiquity many, very many, centuries elapsed before there began in Europe, in the later Renaissance period of the sixteenth century, a serious revival of such collections of animals kept for pleasure.

With but slow increase in these gardens in the seventeenth and eighteenth centuries, there came a great increase of zoological collections all over the world, in the nineteenth century—an epidemic not yet allayed, for the end is not yet.

CHRONOLOGICAL LIST OF DATES OF FOUNDING OF
SOME CHIEF MENAGERIES AND ZOOS

Sixteenth Century

- 1552 Eberdorf
- 1554 Dresden
- 1570 Neugebau

Seventeenth Century

- Middle San Rossore
- 1666 Versailles
- End Cassell

Eighteenth Century

- Beginning Potsdam
- 1716 Belvedere, Vienna
- 1752 Schtubrunn, Vienna
- 1792 Jardin des Plantes, Paris

Nineteenth Century

- 1812 Stuttgart
- 1828 Zoological Society, London
- 1830 Dublin
- 1835 Clifton Zoo, Bristol, England
- 1836 Belle Vue, Manchester, England
- 1838 Amsterdam
- 1843 Antwerp
- 1844 Berlin
- 1851 Brussels
- " Ghent
- 1854 Marseilles
- 1855 Bangalore, India
- 1857 Madrid
- " Rotterdam
- " Melbourne
- Before 1858 Madras
- 1858 Acclimatization Garden, Paris
- " Frankfurt
- 1859 Copenhagen
- " Philadelphia
- " Trivandrum, India
- 1860 Cologne
- 1861 Dresden
- 1862 Rio de Janeiro

- 1863 Hamburg
- " Vienna
- " Munich
- 1864 Moscow
- 1865 Breslau
- " Stallingen, Hamburg
- " Hanover
- " Central Park, New York City
- 1866 Karlsruhe
- " Buda-Pesth
- 1868 Mulhouse
- 1870 Menagerie of Chicago
- " Bombay
- " Blumenau, Brasil
- 1871 Stuttgart
- 1874 Basle
- " Posen
- " Duesseldorf
- 1875 Cincinnati
- " Muenster
- " Jaipur, India
- " Alipore, Calcutta
- 1878 Leipzig
- 1879 Ellerbeld, Germany
- " Taronga Park, Sydney
- 1881 Posen
- " Karaichi, India
- 1886 Aix-la-Chapelle
- 1889 National Park, Washington
- 1892 Mysore, India
- 1894 Bronx, New York
- 1895 Buffalo, New York
- 1896 Koenigsberg
- 1898 Pretoria, Africa

Twentieth Century

- 1900 Halle
- " Kyoto
- 1902 Zurich
- 1904 Milwaukee
- 1906 Rangoon, India
- 1909 Peshawar, India
- 1929 Bern

COSTLINESS OF ZOOS

From the first collection, animals have been costly; only the very wealthy or powerful could finance their capture and upkeep. But in recent centuries they have been handed over more and more to the people as part of the educational and recreational adjuncts of civilization, not merely a luxury, but of importance as part of the apparatus for employing the spare time that seems in danger of hanging heavily on man's hands and full of potential dangers.

In the zoos, society mingles with its modern activities a bit of the observations and emotions that primitive society experienced when wandering as mere weaklings amidst the multitudinous wild things of Nature's Garden.

To stage the Garden of Eden is costly. Zoological gardens, like public schools, are costly and not of such absolute necessity that they can not be dropped in case of war, flood or other disaster, when there is necessity for the saving of sheer life.

In general, the larger number and the diversification of animals increases the whole outlay, but there may be exceptions, as in Sydney when in 1916, with only 700 animals, the expenses were \$32,960 and the income only \$31,625. A deficit is far too common and often it is made good by grants from the government; that is, by taxes on all the people; through gate fees—by tax on those who

visit the zoo as paying visitors; and often by various side shows such as restaurants and concerts. In some zoos, as at Antwerp, there may be successful breeding of costly animals and sales that in 1903 ran the income up to \$100,000 with expenses of but \$24,000.

The greatest zoological garden, the London Zoo, with its 3,082 animals, had in 1923 an income of \$436,970 against an outlay of \$497,655.

In 1916 the great zoo of Cologne had expenses of \$93,611 and only \$70,000 to meet them and care for its 3,109 animals.

In 1922 Pretoria, on the other hand, took in \$55,930 to care for its 1,556 animals, with expenses of but \$37,260.

About that time—the next year, in fact—Kopenhagen had 1,560 animals and took in about \$70,000 to meet expenses of \$91,000.

And still we do not see "every beast of the field" as did old Adam!

SCIENCE IN WAR TIME

We come together at this season of the year to discuss the latest advances in our science and to listen to the announcement of new discoveries. This implies a philosophy of life, an optimistic philosophy; we would not work as individuals nor assemble as societies if we did not believe that science is worth while, and that human progress is both possible, and, for some inscrutable reason, worth working for. This was the philosophy of science in the time of the Greeks, and it is the philosophy of our science of scarce four hundred years' growth. Modern science, I need hardly say, was entirely European

in its origin, as is our American scientific population; and all science is ours to promote and advance by right of inheritance no less than of intellectual sympathy.

Now that the great war is so largely arresting the progress of science in Europe it is our bounden duty to see that there is no halting in America; we should hold fast to our faith and strengthen our efforts for the advancement of science.—*Dr. Frank E. Lillie, in an address delivered before the Zoological Section of the American Association for the Advancement of Science, December 30, 1915.*

LITTLE ACADEMIES I HAVE KNOWN

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I

SINCE the days when Socrates talked and Plato wrote in the groves of Athens, and doubtless long before that, kindred minds have met and by friendly attrition sharpened the edge of keen thinking. Such debates and dialogues led to monologues if one member came to dominate the group. But how comes it that one dominates the others?

Whatever the answer, we find here the germinative stages of the academic lecture and also of modern science, the systematic search for knowledge, *scientia* as opposed to *scientiola*. Many centuries of dialectic muddling elapsed before what we now recognize as valid scientific method emerged, and even now our code is sadly defective. It too often fails us where we need it most—in the resolution of acute problems of human adjustment.

It is a mischievous tradition, widely accepted by both philosophers and men of science, that science is impersonal. It isn't. It can not be. The observations are made by persons who see what they are looking for. The working hypothesis and the experiments designed to test it are conceived in imagination, without which no science is possible, only masses of inert data. The scientific product is what it is because the people who make it are what they are.

The personal equation, then, must be recognized and taken into account in evaluating the product—quantitatively where possible, as in some astronomical observations—but it can not be eliminated from either the method of science or its product. The futile attempt to do so only puts scientific inquiry under arbitrary restraint, limiting its scope and hampering its method, as is tragically

evident especially in the sciences of man in his social relations. Here the things that are really important are the personal attitudes, interests and satisfactions of the people who compose the society, the values which motivate their behavior. Science can not find the answers to the questions that most concern us—how to get along with ourselves and with one another—by ever so clever an application of a scientific method which excludes the essential factors of the problem from its formulation. And this holds for scientific investigation itself, as in every other field.

Most scientific research is properly, indeed necessarily, devoted to the accumulation of factual data and their analysis, with arduous labor and infinite pains. Any competent and adequately trained person can do this essential spade-work. But only a creative intelligence has the insight to recognize the really significant relationships among the data so brought to light. This ability is genius; it is the *Geist* which marks originality in science or any other human enterprise.

Our traditional code of scientific procedure, as a cold-blooded intellectual analysis of the raw data, was elaborated as a guiding principle for the spade-work. Here it has worked out very efficiently, and for these data rigorous quantitative statements is the ideal for which we strive. Yet even here the traditional code has missed something; its neglect of the interest and satisfactions of the worker, that is, of the values inherent in the process of research, sterilizes the product. And now when we turn to the really important work of science, the creative insight of genius, this code fails us utterly.

A million cards assembled by the Bureau of the Census are appropriately punched by intelligent enumerators. The analysis of the data recorded in accordance with any one of the standard categories established by the system of punch marks previously adopted is done rapidly and accurately by a machine. This mechanism "knows no values" and requires none. It delivers the totals analyzed according to the prearranged schedule of categories. It may tell us how many employed men there are in Detroit and what they bought with their wages. But now, if one asks the machine a question not provided for in the original design of the punch marks, he gets no answer. Our traditional scientific code, like the sorting machine, may give us objective and accurate answers if we know what questions to ask of nature; but it requires a live genius, not a dead machine, to think up really significant new questions and then find the answers. Here the sorting machine breaks down.

A de-humanized science is a dead machine which can do some routine things very well. But actual science is not dead and the great scientific discoveries have not come by close adherence to the standardized formulas of mathematical precision or logical rigor. The flash of insight which starts a genius on a long series of observations and experiments resulting perhaps in the validation of a new scientific principle doubtless has causes. And these causes are to be sought within the person of the man, not in any adventitious external happenings. No external event can give us insight. An original idea will not be generated if the makings are not already there in the conscious and unconscious organization of its inventor.

The motives which generate scientific work and sustain it, the intelligence which directs it, and the satisfactions of successful achievement are not merely

the tools of science or by-products; they are integral and vital parts of it. The increasing volume of protests against the traditional dogma is a hopeful sign that the humanistic components of science are at long last receiving their due attention, as expressed, for instance, by John C. Merriam: "In the end I believe we have come to see that the scientific method is characterized in considerable measure by attitude of mind and desire for truth rather than by complete mathematical-physical solutions of questions."

This is why intimate biographies of successful men have so strong an appeal, and the autobiography is the most valuable source-book of science. For the extracurricular interests and activities of scientific men reflect their own inner natures and so give invaluable help toward a true evaluation of their work. Science is a social enterprise, "a cooperative effort toward a united understanding" (Edwin B. Wilson), and it is profitable to examine its social components as seen in association of informal groups or organized societies. This thought has led me to assemble these personal reminiscences of the Little Academies.

II

In the biography of Louis Agassiz¹ we find perhaps the most typical picture of unusual native ability directed with singleness of purpose and consummate industry toward researches in natural history of wide scope and scrupulous fidelity to detail. This child of a Swiss protestant clergyman had an understanding mother who was his teacher and who fostered his individuality, incomprehensible to her though it came to be and even though it involved the transformation of the parsonage into a veritable museum of all manner of outdoor litter and a menagerie of all kinds of wild pets.

¹ E. C. (Mrs.) Agassiz, "L. Agassiz, His Life and Correspondence," 2 vols., London, 1885.

We know of no external influences which lighted the flame of spontaneous enthusiasm for nature which led him from infancy to learn the ways of every wild thing before there was anyone to tell him even their names; to write at fourteen years of age a program of his future life which included a career in both science and literature with a long list of the books to be procured immediately, extending from Strabo in the original Greek to the latest geographical charts; to plead with his parents to allow him to go to the university instead of the business calling laid out for him; to take the medical course as lying closest to the study of nature which he had at heart; and in spite of an "invincible repugnance" to the practice of medicine to complete the medical course while ardently devoting himself to his real interests in comparative anatomy and paleontology.

While studying in Munich a group of about half a dozen students used to assemble in Agassiz's lodgings for discussion of the day's work and of things in general. The themes were taken chiefly from their own extracurricular studies of comparative anatomy and philosophy. In these sessions each of these remarkable students gave to the others a more or less formal lecture on some subject related with his own study, and the following debates often extended far into the night.

So serious and diligent were these boyish enthusiasts and so strong was their influence upon the university community that these informal meetings came to be called the "Little Academy," a university within the university. How many American students of to-day would take kindly to their daily program? From six to seven o'clock mathematics; from seven to eight breakfast prepared with their own hands; at eight a clinical lecture in medicine; at ten a lecture on mechanics; at eleven twice a week a lec-

ture on the natural history of amphibians; from twelve to one lectures on the sense organs. Dinner was at one o'clock in a quiet private house at a cost of nine cents each. Then chemistry with experimental demonstrations, and at three lectures on entomology. On Saturday a lecture on experimental physiology and two on philosophy, or perhaps one in theology on the philosophy of inspiration. Thus the days are filled until six o'clock. Possessing but one pot, which had to be used during the day for boiling up the bones needed for their studies in comparative osteology, at evening they cleaned it out (I presume they washed it; the record is silent on this point) and cooked their simple supper. Then followed the long evening of study, discussion, or the more formal sessions of the Little Academy.

In this setting we see the workshop in which some of the great naturalists of the nineteenth century were forged. Agassiz supported himself on an income of \$250.00 a year, which his father managed to save out of his own meager salary. From this he paid the university bills, bought the necessary books and kept in his employ one, and occasionally two, artists to illustrate his researches. "But they," he says, "were even poorer than I, and so we managed to get along together." Before Carlyle penned the *Sartor Resartus* this youth had learned his secret: "Produce! Produce! Were it but the pitifullest infinitesimal fraction of a product, produce it, in God's name! 'Tis the utmost thou hast in thee; out with it, then."

III

The Academy instituted by Plato in 387 B.C. set the pattern and inspired the ideals of succeeding learned societies up to our time. But independently of this tradition, and doubtless often in complete ignorance of it, similar associations have sprung up as if by spontaneous

generation wherever active and inquiring minds have met. Examples of this in our own time are everywhere about us. In addition to formally organized stable academies and similar associations of mature scholarship, there arise in almost every cultured community sporadic and frequently ephemeral societies generated by similar cravings for new experience and opportunities for self-culture and expression. It has been my good fortune to participate in several of these, some in college and university circles and some untrammelled by any academic traditions. Here I have found some of the richest sources of inspiration and scientific fellowship. The first of these was a formally organized college association.

On the 16th of April, 1887, my brother organized the Denison Scientific Association. I was the youngest charter member, being then a student in the preparatory department of the college. My pride in this membership is greater than in that of any of the other scientific societies with which I have been connected since that time. The association has an honorable record in the promotion of scientific work; its *Bulletin* is now in its 44th volume; and nearly all these pages record creditable scientific work by members. Perhaps the most valuable contribution to science made by this association is the intangible influence upon its membership and the college community in general. It was my privilege to attend the meeting commemorating the fiftieth anniversary of its founding, when I said:

The key-note of the movement from its inception was, "Find it out for yourself; take nobody's word for it." The membership was composed chiefly of undergraduate students and the primary function of the organization was evidently the stimulation of interest and training in the method of science. The immediate success of the enterprise can be measured in two ways. First, by the surprising number of contributions to knowledge deemed worthy of publication made by the students themselves and by junior members of the faculty; and, second, by the reflex effect on the educational policy

and actual class-room practice of the college as a whole. The significance of this second point should not escape us. It is a remarkable fact that nearly half of the student charter members came from the classical, not the scientific, course and two of the five faculty members were teachers of Latin (Chandler) and Greek (Johnson) respectively.

In an address delivered on the date of this semicentennial Professor Carey Croneis said of the twenty-seven charter members:

They were all young, most of them in their twenties, but a great many were to attain national, and even international distinction. Of the group, thirty per cent. were later listed in "Who's Who in America." A half dozen were starred men in "American Men of Science," and two of them became members of the National Academy of Sciences. As far as can be ascertained, practically all of the twenty-seven gained some real distinction in life, interestingly enough some of them in fields quite distinct from science. . . . Herrick's influence remained strong on all of these early associates. He was the central figure in a group whose members considered themselves his disciples. . . . In a very real sense, then, Denison's little science nucleus, with C. L. Herrick as its mentor, may be compared, and favorably too, with the Agassiz or Shaler circles at Harvard, or the famed University of Kansas group under Professor Williston, the latter having been active at almost precisely the time that C. L. Herrick was at the height of his inspirational career.²

Some years later, when I was a junior member of the faculty of this same college, a few of us, representing as many departments of science, met every Sunday evening to talk things over, particularly what we were doing with our headpieces. It came to be customary that as each in turn led the informal talk of the evening he reported to the others what he had achieved in research, in reading or in constructive thinking since his last report. To come unprepared with some contribution was so embarrassing that this did not happen a second time. The personnel of this Little Academy shifted somewhat from year to year, but its influence was stable, and at least one of its members looks back upon the decade of

² Carey Croneis, *Denison University Bulletin*, 32: 133-144, 1937.

his connection with it as the seed-time of many later harvests. It is true that many of these seeds were late in germination and were quickened, perhaps by sun and rain in solitary walks of later life or in the seclusion of the study after years of patient laboratory observation and accumulation of apparently trivial details.

Not all the sessions of this academy were held within college walls or at the stated weekly meetings that our colleagues called our "Sunday School." All-day field meetings were not uncommon. The geologist would take us across-country to see a "fossil river" whose preglacial course would be followed mile after mile as a wide and winding valley now floored with fields of grain to end in some late glacial moraine which blocked the ancient channel and diverted the water to a new course.

At noon-time with weary limbs stretched on mossy cushions overlooking a narrow rocky gorge the history of the little brook below would be read backward ten thousand years, all as clearly written as if human eyes had seen it and made a record in print or on tablets of sculptured stone. An ancient rivulet captured and impounded by dams of ice or glacial moraine; a wide lake quickly filled by melting ice; the overflow through the lowest col between the rimming hills; and the slow etching of a new channel deeply incised in native rock until the lake was drained and our brook, its more strenuous task accomplished, murmurs contentedly over the pebbles in the gorge at our feet.

Trailing fossil rivers may be as thrilling sport as the hunting of the snark. You charm them with smiles and with soap; you threaten their lives with a railway share; and you march uncounted leagues in sun and frost over hills and fields and squashy swamps. And all the while the mind of the academician is projected outward alert for clues pointing the way and inward probing for for-

gotten experiences which, though apparently irrelevant, may tie into the present problem with some unexpected relationship.

At this time the summers were spent at Woods Hole, where a Great Academy, the spiritual and physical offspring of Agassiz's Little Academy, then, as now, brought together the most fertile scientific minds of our continent. A few years later we of the little midwestern college developed our own summer laboratory, which our students dubbed "Woods Hole Junior." Through the kindness of a neighboring farmer we secured a lease of one twentieth of an acre of pasture land—duly surveyed and recorded—which included a free flowing spring. Here a tiny laboratory building was erected over the running water and in a near-by tent one or more members of our Little Academy slept regularly for several successive summers.

The routine of the daily sessions was simple—and productive. Up at dawn. Breakfast cooked at open camp-fire outside. Then steady work at the microscope for four or five hours. At noon a ten-minute walk across the brow of the hill took me home to a hot dinner. Then correspondence and routine professional duties until late afternoon, and over the hill again with a hamper containing supplies for the next camp supper and breakfast.

Our camp was out of sight of the college or any other buildings and of any road. The seclusion was perfect. My wife entered into the spirit of the game and if, during the forenoon, telephone or other calls came for me she would reply:

"He is out of town."

"When will he be back?"

"About one o'clock."

This harmless fiction was kept up for two successive summers before town and college people saw through it, though at no time were we more than fifteen minutes' walk from the college offices.

This period marked the high-water

mark of this Little Academy. After a camp supper the long evenings were spent before an outside fire. Sometimes only one member would be in attendance. More often a colleague or two or three, with perhaps wives and children and a guest. And always a dog. Then the visitors would be escorted under the stars through the dewy pastures to their homes and soon we would be in our own blankets by the banked bonfire. At daybreak a dip in the watering trough of the pasture fed by cold spring water opened the next session of the academy.

On Saturdays during the school sessions the field meetings of the academy would occasionally be attended by visitors from the neighboring state university. The long-legged zoologist and the psychologist whose shorter legs were encased in seven-leagued boots of new moose-hide would drop down into Woods Hole Junior before the morning was old. Meantime the resident academicians had set a pot of beans a-baking.

Real camp-baked beans are a delicacy which few people nowadays can enjoy. Ordinary navy beans will do on a pinch, but the true academician will find the genuine New England yellow-eyed beans. First dig a pit about three feet deep. Line it with small field stones. Over it build a huge fire of oak, hickory or other hard wood until the pit is filled to the brim with glowing coals. Meantime the beans have been parboiled in an iron pot over an open fire, just the right proportions of salt pork, molasses and other ingredients added; over the pot lid a tin pie plate is inverted. Then with a long-handled shovel the live coals are quickly scooped out, the pot is lowered into the pit with appropriate incantations, the coals are shoveled back over it and the top covered with a few inches of dry earth. Next, walk twenty miles. At sundown the homing instinct will bring the academicians back to the bean pot. If this recipe is faithfully followed, it is guaranteed that the bean-hole will yield

food fit for any immortals on Earth or Olympus—and no beans will remain in the pot at bed-time.

Those Saturday walks were exercise for mind as well as body. The curious ways of man came in for due share of attention. Sprawled in the sun on the crest of one of the denuded Welsh Hills with head pillowed on a lichen-covered stone and feet buried in ruddy sheep-sorrel, the scene would suggest a question. Upwards of a hundred years ago the first settlers penetrated this wilderness. They came direct from Wales. With hundreds of square miles of virgin land before them, all to be had for the choosing, why did they pass by the rich bottom lands and settle on these steep and rock hills? In the fertile valleys by which they are surrounded are now the richest farms in the world. On these barren slopes the hardy descendants of those hardier Welsh pioneers still wrest a meager living from the pockets of soil between the stones of their ancestral hills.

Why? Did they foresee two generations of fever and ague in the malarial thickets of the swampy bottoms and rugged health on the uplands? Did they weigh over against bounteous harvests of golden grain and golden coin in the lowlands the harvest of men, the staunchest and best our country has produced, which has since been reared on these uplands? I doubt it. The hill-man loves hills. It is bred in his bone. He does not argue about it. He does not sentimentalize about it. He lives it. And given hills with contentment, he is content.

IV

In this same period another group of naturalists began to tread the shifting sands of the Indiana Dunes at the south end of Lake Michigan. Small groups of two to six men would go out from Chicago at the week-end and spend a long day tramping the wastes of sand and forest to watch the dramatic conflict

of these natural enemies and talk of many things. The people of the group were rarely the same on two successive weeks, but a few of the men were regular attendants of these sessions of what I came to call the "Dune Academy." Among the early votaries were Whitman, Coulter, Cowles, Child, A. P. Mathews, Waldemar Koch and other distinguished members of the University of Chicago in its early years. My connection with the Dune Academy began in 1907 and continues until now. With the transformation of most of that region from the primeval wilderness of early days to clustered summer homes with paved roads and tidy lawns its charm for the true academicians has vanished; yet fortunately there still remain some secluded spots quite unspoiled for us, and occasional week-end sessions of the academy continue.

The memories of those early days when one could walk for twenty miles with scarcely a trace of human meddling are very precious. Then we would wind our devious ways from lake beach to drifting sand, through thorny scrub and noble forest, to settle down at last in mid-afternoon around a little fire, a pot of tea and a bite to eat. With pipes lighted and weary muscles at rest the talk would drift from shoe-packs to Schopenhauer, with a tinge of pessimism perhaps at both ends of the argument but never all the way between. Especially in winter, when drifting snow was piled on drifting sand, the afternoon lunch at a campfire in the lee of a sheltering dune and protected by low-hung branches of pine was always enlivened by animated discussion. Newly discovered facts were spread before us for comment and every interpretation was subject to merciless criticism. Several notable books were incubated in the warmth of these discussions.

But not all these sessions were so animated. The fact that other members of the party failed to attend never led to

an adjournment, for one is a quorum of the Dune Academy and every academician has learned to get along comfortably with himself. A solitary noon camp sheltered under snow-festooned pines has featured some of the most inspiring sessions. In the troubled September of 1917 I spent four weeks in a tiny shack on the front dune looking over the Lake, alone except for an Airedale dog. In later years much writing was done in a similar cabin in the same neighborhood.

V

The next chapter in the history of Little Academies I have known takes us forward to that era when the Model-T Ford was the most popular means of locomotion in this country. The appanage of the peripatetic academy was enlarged to embrace the effective range of a flivver tramp. Camp equipment was always stowed in or around the car when we set out for no destination.

The annals of what may be called the Flivver Academy include the log of many such aimless wanderings, some by flivver, some by other means of transport, and some reaching no farther than the range of vision from study windows. For the qualifications for membership in this academy are defined in terms of mental attitude rather than by actual propinquity in space and time. These holiday adventures would take us too far afield for narration here. One incident must suffice.

We had motored up to the north end of the Iron Range in Minnesota. Here we parked the car and took to the water for change of scene and because that was the only way to go any farther in that direction. We claim to be good flivver tramps but not good fishermen. In proof of it we carried no tackle into unsurpassed fishing water and ate Alaska salmon from tins. What business, then, had we there? None whatever. But to flout the rules of logic and convention is the flivver tramp's inalienable right.

We came into the fisherman's paradise, we saw, and we did not fish. Who is the worse for it? Not the fish. And we got what we went after, a better record than some fishermen can boast.

We were in camp at Knife Falls on the international boundary, accessible only by canoe and the take-off for hundreds of square miles of more canoe-country in the hinterland. No other transport was available. At the head of the portage around the Falls is a tiny campsite. It was late afternoon. A party of four men came up, the canoes neatly balanced on the shoulders of the guides and the two fishermen carrying the duffle. One of the latter was obviously a fisherman in prospect, not in retrospect. For, item first, he wore a straw hat. Item second, while the other three men rustled up wood and supplies to make supper he sat down on a log and began to talk with me, an unknown stranger, about metaphysics.

The details of the argument I have forgotten, but the upshot of it was that the findings of Einstein have forged the last link in the chain of evidence demonstrating the truth of the idealistic philosophy.

I did not learn his name and we parted within a third of an hour. He may have been a university professor, an eminent divine or an iron-monger; he certainly was a Scot. Though you bray a Scotchman in a mortar, yet will not his metaphysics depart from him.

VI

Informal groups of earnest searchers for scientific knowledge spring up in unexpected places. Before the Great War a group of Chicago men gathered around the magnetic and lovable personality of the late George Burman Foster. They wanted to know how we lived and why, and how to do it more successfully. When Mr. Foster came and asked me to guide their discussions of the application

of biological principles to problems of human experience and conduct, I said, "No. I am not a parlor lecturer and I have no ambitions in that direction." But later when he invited me to his house to meet the group socially I could not well decline. The twenty men presented a representative cross-section of Chicago's more thoughtful population—merchants, lawyers, physicians, architects, clerks, stenographers and a telephone lineman. All were busy people, some were men of large affairs, and all were alert, keen and critical.

I could not resist them. The result was that for twenty consecutive Thursday evenings, including Thanksgiving and Christmas, most of these substantial citizens sacrificed every other engagement to participate in these discussions. A systematized lecture was impossible. Within fifteen minutes the leader was bombarded with questions which cut down to the marrow of the subject, and he admits that after each three- or four-hour session he was too thoroughly exhausted and at the same time nervously tensioned to think of sleep for several hours.

There was no financial consideration involved. We all entered into the game for the joy of the sport, though in later years some of the lecturers were paid. Years passed and this group continued to hold regular meetings. The numbers increased and naturally the sessions were not so informal as at first. After Mr. Foster's death and my withdrawal, Clarence Darrow was the natural leader. His abounding energy and Irish wit, the unpredictable output of his whimsically illogical mind, his warm human sympathies and generous nature would hold the group together during the discussion of the most controversial social questions. What came to be called "Mr. Darrow's Biology Class" was known to but few people, yet its influence upon the cultural life of a great city was undoubtedly far-reaching.

A long time afterward there was an unpleasant repercussion of these conferences. One of the stories I told apparently seeped out to an adsmith for, in looking over the morning paper one day, I was disagreeably surprised to see, blazoned across the top of a full-page advertisement of a shoddy pulp magazine, my name cited as the source of the story. It was a good story—not original with me—and its unauthorized use was not legally actionable in either case. The situation resembles Kipling's version of the circumstances "when 'Omer smote 'is bloomin' lyre"—

An' what he thought 'e might require,
'E went an' took—the same as me!

This advertisement appeared in many of the largest newspapers of the country and its author, if he should chance to read this, may be surprised to learn that if he had come to me and offered \$10,000 for this use of my name I would have told him to go to perdition.

VII

My most recent attendance at a Little Academy was as thrilling as it was unexpected. In the course of a long pilgrimage by motor down the West Coast we paused to attend some sessions of the Stanford meeting of the American Association for the Advancement of Science. Here our largest and most influential scientific organization and the smaller satellites which revolve about it in more or less eccentric orbits presented an impressive demonstration of the social values of science in formal array. The Little Academy meeting to which I refer was the antithesis of this in every superficial aspect, and yet it approached the Platonic ideal, I venture to say, as closely as we can ever hope to attain under modern conditions.

On Sunday morning the contemplated trip to the Yosemite (which I have never

seen) was abandoned to accept an invitation by Professor and Mrs. Chauncey D. Leake to lunch at their summer cabin, "Casa de los Medicos e Farmacos," near Boulder Creek and the "Big Basin" in the redwood forest of the California Coast Range. The guests were Dr. E. G. Conklin and Dr. Olof Larsell (both of whom were sometime Dr. Leake's teachers) with Mrs. Larsell and the writer.

Here during the lunch hour various others drifted in until all the members of Dr. Leake's Department of Pharmacology and their wives were present. Then to the surprise and delight of the guests we were assembled in a tiny natural amphitheatre formed by a circle of closely set redwood trees containing in the center a little open fire for warming the coffee and around this a row of benches. After enjoying Mrs. Leake's refreshments, Professor Leake opened one of his regular departmental seminars, introducing first Dr. Otto Gutten-tag, who gave a scholarly presentation of some German contributions to the philosophy of biology. He was followed by Dr. Charles Gurchot, a Frenchman, who, as was to be expected, subjected his German colleague's argument to pungently critical analysis. After some general discussion Dr. Conklin's extemporaneous summary of current trends in philosophical biology was a masterpiece of clarity and simplicity.

Here in the shadows of the dense redwood forest, to the accompaniment of the murmuring of a mountain brook and with passages of sharp controversial debate punctuated by vivid pencils of sunlight filtering through the lofty treetops, we found the ideal Little Academy. In an impressive natural setting whose majestic proportions favor an attitude of becoming humility and reverence this informal seminar seemed to the fortunate guests to approach perfection in spirit and method.

PHYSICS AND INVENTION

By Dr. C. F. HAGENOW

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A GENTLEMAN of my acquaintance, eminent in his profession, once asked me: "What are physics?" It was by no means an isolated instance; I have often been asked this question, though usually not in this singular (or should we say plural?) manner.

What is physics? One of our great American physicists, Henry A. Rowland, defined it as the "science above all other sciences, which deals with the foundations of the universe, with the constitution of matter from which everything in the universe is made, and with the ether of space by which along the various portions of matter forming the universe affect each other." No doubt the chemist will object to this statement as being altogether too inclusive. It is always a matter of humorous debate whether chemistry is a branch of physics, or physics a branch of chemistry. Regarding the matter from a practical standpoint, physics can truly be said to be the basis of most engineering. A single discovery in electricity by a physicist has made possible our huge electrical industry, and everything that has to do with mechanics, heat, sound and light is at bottom a problem in physics.

Perhaps the chief reason why the question: "What is physics?" is asked more often than "What is chemistry?" or "What is zoology?" is to be found in the word itself. This goes back to Aristotle, who used the word physics to include the study of all inanimate nature. It does not lend itself to variations as familiar as "chemical" and the "zoo." The older term for physics, *viz.*, "natural philosophy," is scarcely more suggestive. The adjective form of physics is "physical," and this word, unfortunately, has a number of other meanings unconnected with the subject of physics. Physical education does not mean education in physics, nor are phys-

ical exercises experiments in physics. An amusing instance of confusing the two meanings occurs in a large and important German work on physics in which the authors interpret the statement "physical exercises for children under seven years of age" as signifying exercises in physics for these children. A physical laboratory is, therefore, no place for physical exercises!

I believe that physicists, and possibly many of my readers, are getting somewhat bored with the oft-told story of Franklin's rejoinder to the perennial question, "What is the use of this?", so often asked concerning a piece of research that has no obvious practical application. But the question seems to be exceedingly long-lived. Faraday's reply to Gladstone is very much to the point and has also been often repeated. It may not be entirely a work of supererogation to give it again as especially relevant to this article. On being asked the usual question as to the practical value of the device he was showing Gladstone, Faraday very significantly replied: "Some day you will be able to tax it."

Here is an original story the reader has probably not yet heard. A student once made this startling announcement in the course of a discussion on the attributes and comparative merits of scientists and inventors. Said he: "The inventor uses his brains, the scientist finds out things by accident." Rather hard on the poor scientist! Now it is a fact that accident does sometimes enter in; the really vicious thing about this slipshod verdict of many people on this phase of the subject is that they utterly fail to take into account what I may call the "setting" of this event. This is another illustration of a dangerous half-truth. Just one example will make this clear. Consider the discovery of x-rays

by Röntgen in 1895. It was briefly as follows. Working with a vacuum discharge tube, covered with black paper, Röntgen found that a fluorescent screen, located at some distance from the tube, became luminous when the tube was in operation. Evidently, under the conditions of the experiment, this could not be due to visible light. Then he found that this same invisible radiation could penetrate thick books, wood and thin sheets of metal. Now consider the two elements that made this accident possible. First, Röntgen was pursuing studies on the electric discharge *in vacuo* that were begun about forty years before and had been developed by a number of investigators, notably by Lenard and Crookes. Secondly, Röntgen did not fail to take note of the new phenomenon; it might have (and probably had) escaped hundreds. There was required, then, the presence of an experienced and trained investigator. Pasteur said: "Chance favors only the prepared mind." The reader will agree that here was a truly elaborate setting for this "accident."

I must point out at once that the terms scientist and inventor are of course not mutually exclusive; many men have been eminent in both fields. But I wish to draw a distinction, for the purpose of this article, between the research worker in physics and the inventor who does not discover the physical phenomenon that he applies to his invention. It is perhaps unavoidable that the public should first become acquainted with certain physical phenomena through their successful applications in everyday life, i.e., through the inventions. But it is at once surprising and disheartening to realize what misconceptions otherwise well-informed persons have concerning this relation of invention to research. Now it is quite correct to say, for example, that S. F. B. Morse invented the electric telegraph, if we mean by that that he devised a specific, practical application of a principle already known and

used before him. How many know that such eminent physicists as Gauss and Weber in Germany had used an electromagnetic telegraph, though not primarily for telegraphic purposes? Their receiving instrument forms the basis of the reflecting galvanometer used in cable telegraphy. In this country Joseph Henry, also, devised an electric signaling apparatus that rang a bell through more than a mile of wire. Henry never filed a patent. In acknowledging Morse as the inventor of the telegraph, known by that name, he recorded a number of his claims, among which I shall mention only one, which many readers will recognize as the principle of the operation of the modern telegraphic sounder. Quoting Henry, "I was the first to actually magnetize a piece of iron at a distance, and to call attention to the fact of the application of my experiments to the telegraph."

Now some one may wish to interject a remark something like this: "But Gauss and Weber did not invent a practical and commercially usable device." That is true, and I may add that they were probably neither interested nor, perhaps, particularly capable of doing so. Gauss, incidentally, did request others to simplify and render more practical this apparatus. I doubt if Faraday, who discovered the principle on which our entire electrical power industry is based, could have been induced to desist from his researches to develop the essential principle of induced currents. Strange as it may seem to many a practical man, the pecuniary advantages of such an undertaking would have been among the least inducements. There have been and are such people. Pasteur, who certainly can not be accused of having contributed nothing useful to society, said to his students: "Your business, your especial business, must be to have nothing in common with those narrow minds which despise everything in science which has not immediate application." Dr. Abraham Flexner made

what may seem to many a rather harsh comment on the common notion of a great "scientist." When he asked George Eastman, who in his estimation was the most useful worker in science in the world, Mr. Eastman replied: "Marconi." Dr. Flexner surprised (and probably shocked) him by saying: "Whatever pleasure we derive from the radio or however wireless and the radio may have added to human life, Marconi's share was practically negligible." What Dr. Flexner meant, of course, was the fact that the theory of electromagnetic waves (and a bold theory it was!) was worked out by Clerk Maxwell about 1866 and brilliantly confirmed in 1887 by the epoch-making experiments of Hertz. It was then that the inventor stepped in. The wireless waves, methods of producing and detecting them (all very primitive, it is true) were there, and it remained for the ingenuity and inventive skill of Marconi and many others to develop the system of communication and broadcasting as we know it. I realize that this is stating the case in the broadest outlines only. It is scarcely necessary to add that this development involved many discoveries and elaborations concerning which one might have some difficulty in always distinguishing between the results of "pure science" and those of "invention." A curious bit of physics history is that of a discovery of Edison in the late seventies. It is still known as the "Edison effect," the explanation of which was not forthcoming for many years. It illustrates the principle of the two-electrode radio tube, or diode, often used as a rectifying detector. Adding a third electrode, the grid, a stroke of genius by Lee De Forest, gave us our modern radio tube. Now more electrodes have been added and we have the screen-grid tube, the pentode and others.

How many persons know the names of the prominent physicists among the allied nations who, during the world war, helped to solve the problem of submarine

detection? As Rutherford said, it was a problem of physics, pure and simple. It was not a problem of engineering at first. The most successful detector was a modification, by our physicists, of a French device. The credit seems to belong chiefly to Langevin, in France, and to Mason in this country. There were many other contributions by American physicists. For example, a system of signalling by infra-red rays, developed by Theodore Cross; another system, using ultra-violet light, by Robert Wood. There was a leak-proof gasoline tank; a new range finder due to Michelson. A method of locating the enemy's guns by sound plotting was devised and used with great success. Remarkable improvements in aerial photography, through the agency of color filters, increased the visibility and the power of detecting camouflage. Many more of such instances could be cited.

It is to be noted that the problems just mentioned were solved by men who had no special knowledge of many of the engineering and practical features of the matters concerned. It was much more to the purpose that they had a fundamental knowledge of the principles involved and the trained minds to apply those principles. I am reminded of the remark of a friend of mine who had just been offered and had accepted a very fine position with the American Bell Telephone Company. "I do not know anything about telephones," he told me. But he knew the physics and mathematics of electricity, mechanics and sound, which was just what was wanted. There were plenty of men who knew all about the telephone as it was then used.

Poincaré remarks:

One has only to open one's eyes to see that the triumphs of industry which have enriched so many practical men would never have seen the light if only these practical men had existed, and if they had not been preceded by disinterested fools who died poor, who never thought of the useful, and yet had a guide that was not their own caprice. . . .

No one needs to be told of the intensely

practical benefits to humanity resulting from the work of Pasteur, whose admonition to his students has already been quoted. According to Thomas Henry Huxley, Pasteur saved France a sum equal to the total war indemnity of 1870-1871. It was also Huxley who remarked:

I weigh my words when I say that if the nation could purchase a potential Watt, or Davy, or Faraday, at the cost of a hundred thousand pounds down he would be dirt-cheap at the money. It is a mere commonplace and everyday piece of knowledge that what these men did has produced untold millions of wealth, in the narrowest economical sense of the word.

After one has learned the economic value of only a single discovery of Faraday he will agree that Huxley's estimate is far too modest.

Coming to the present, here is an evaluation of a particular research problem in actual money. Dr. William D. Coolidge, director of the research laboratory of the General Electric Company, made the following statement about a year ago, before the Temporary National Economic Committee:

If the light used in 1938 had been provided by the lamps of 1900, with the electric power rates of 1900, the cost would have exceeded that of 1938 by over \$10,000,000,000, or about \$30,000,000 per day. Of course the public would get along with less light, for they could not have afforded such a lighting bill. What that would have meant in reduced safety and efficiency in industry, in reduced safety on streets and highways, and reduced comfort and convenience in the home can not be evaluated in dollars.

A good example of a very important physical phenomenon which seemed at first to have no conceivable practical use is the photoelectric effect, *viz.*, the emission of electrons from the surface of many elements when they are illuminated by light. This photoelectricity is responsible for the sound production in our talkies. This phenomenon is also the basis of the photoelectric eye and a score of other useful devices. The spread in time between discovery and its application is becoming shorter and

shorter. Very recently the study of the structure of the atom by the cyclotron has led to a means of creating artificial radioactivity, which is used in hospitals when some kind of radium treatment is indicated. We are now hearing rumors of fantastic amounts of power that may be derived from the splitting of a certain uranium atom. It is safe to say that almost any discovery in physics will some time prove to be of practical use, but do not expect the experimentalist to justify his efforts by pointing it out in advance.

Sir W. H. Bragg has expressed himself on this general subject so beautifully that I am sure it is very worth while quoting him here. He says:

It is simple and fascinating to suppose that a new invention is found as complete and clean as a nugget of gold, as unexpected and as unconnected with its surroundings, and finally as readily convertible into cash. The truth is different. Science does not increase by the constant addition of new facts to old, as a museum collection increases by the addition of new specimens. Science grows like a tree which shoots out new branches continually, and at the same time strengthens the old; twigs become boughs, and boughs become great stems, while the tree is always growing higher and higher into the light and more firmly based below. Science is like a tree also in this, that both need wise cultivation. The nourishment of the tree, its training, and its pruning, have their true counterparts in the development of science, and in both cases the fruit comes as the reward of skill and labor. This is the thing so hard to understand and yet is so important. The fruits of science are first seen when they are brought to market, and it is vaguely supposed that they have been picked up somewhere and somehow in the condition in which they appear. Perhaps they were made by the man who carries the basket. It is not realized that the fruit comes at the end of a long process, and that even a little application of science may be the result of many years of unseen growth and labor.

Sometimes the priority of the research worker is not only not acknowledged, but he is even accused of lagging behind the inventor in his knowledge of nature. The scientific man is thus represented as extremely conservative, not to say an "old fogey" and is described as being brought to grief by the more enterpris-

ing inventor. A magazine article of some years ago is a case in point. It may be of interest to give this material in some detail, as it is so typical of that kind of disparagement. The article in question had to do with Edison's work on the incandescent lamp. Here I might remark that Edison's wonderful and monumental achievement in perfecting this lamp is a good illustration of a case where the inventor merits the lion's share of the credit. The pure physics of the phenomenon of a thin filament being heated to incandescence by an electric current does not loom very large in comparison.

I shall consider only one item in this article, but it will serve to illustrate the method of the writer, who made a naïve and perfectly superfluous attempt to add to the glory of one of the greatest inventors of all time, Thomas Alva Edison. This author claimed to show that certain high authorities in electrical science did not understand the laws of divided currents. As is so often the case when quotations are used to prove a point, everything is omitted which is at all unwelcome to the writer's purpose. Here is the quotation, as given in the article in question, taken from Tyndall's essay on "The Electric Light."

I believe I am credited with knowing something of the intricacy of the practical problem involved, and the most that I can say in answer is that I should certainly prefer to have it in his [Edison's] hands than mine.

Now as to Tyndall's own discussion of the subject, which is quite conclusive. After taking the greatest pains to explain the distribution of the current from the mains to the consumer and back again to the source (according to laws known years before) Tyndall goes on to say:

This, if I understand aright, is Mr. Edison's proposed mode of illumination. The electric force is at hand. Metals sufficiently refractory to bear being raised to vivid incandescence are also at hand. The principles which regulate the division of the current and the development of its light and heat are perfectly well known.

There is no room for discovery, in the scientific sense of the term, but there is ample room for the exercise of the mechanical ingenuity which has given us the sewing machine and so many other useful inventions. Knowing something of the intricacy of the problem, I should certainly prefer seeing it in Mr. Edison's hands to having it in mine.

As against this style of biographical writing note the following from Lucien Poincaré:

It would be a delicate and also a rather peurile task to class men of genius in the order of merit. The merit of an inventor like Edison and that of a theorist like Clerk Maxwell have no common measure, and mankind is indebted for its great progress to the one as much as to the other.

Wilbur and Orville Wright expressed their indebtedness to Langley in the following words:

The knowledge that the head of the most prominent scientific institution of America believed in the possibility of human flight was one of the influences that led us to undertake the preliminary investigations that precede active work. [Professor Langley was secretary of the Smithsonian Institution.] He recommended to us the books which enabled us to form sane ideas at the outset. It was a helping hand at a critical time, and we shall always be grateful.

Langley did pioneer work in theory and experiment at a time when a man was ridiculed for his pains. Langley's power-driven model flew for one and a half minutes, until the fuel was exhausted. The distance was a little over a mile. He thus established the possibility of free dynamic flight. Another machine of his, which failed spectacularly at the first trial, made a flight with a pilot after Langley's death. It is difficult to realize that in our lifetime popular derision could stop the investigations of a man of such scientific attainments as were Langley's. The reader may recall a recent statement by Lindbergh, who said that one of the important needs of aviation was research in that field.

The student of the mathematical and physical sciences has sometimes been reproached for devoting his talents and energy to purely abstract enterprises when such talents and energy could be

much better employed for more pressing and important problems, such as may be designated broadly as social problems. This phase of the subject can be best introduced by a remark by a prominent person along this very line. I do not remember the exact words, but I do remember very distinctly that he disparaged the undue attention paid to what he called cold mathematics. Now your radio waves were once only the cold mathematical equations of Maxwell. Do you remember that you once learned in your algebra course that the square of any number, positive or negative, was always positive? In the inverse operation, the square root of a positive number may be either positive or negative. So far there was no way of extracting the square of a *negative* number. Quite a while ago some one wondered what would happen if you *assumed* that you could do this also. What sort of a number would result? You know the pure mathematician has no regard for realities. So in spite of the fact that it was "impossible" to extract the square root of a negative number and get a "real" number, the operation was assumed possible and the resulting number was called an "imaginary number." This name has persisted to this day, though the number is no more imaginary when properly used than is a common fraction. Now this "imaginary" number has proved to be of the greatest importance in the thoroughly practical business of alternating current engineering. The symbol for the square root of minus one is the letter i , though the electrical engineer prefers j . The gentleman who complained of the frigidity of mathematics probably did not realize that his house lighting, and all the benefits he enjoyed from the convenience of the electrical industry, with all its social implications, were all greatly advanced by this once impossible number, the square root of minus one.

An amusing illustration of the utter ineptitude of a certain book reviewer to evaluate physics as a factor in society

occurred during the World War. Dr. Millikan was publishing his book "The Electron," not long after his famous researches on the isolation and exact measurement of the charge of the electron. To a certain reviewer this book, dealing with such a tiny thing as the electron, appearing at the time of a world war, seemed so incongruous that it strained his vocabulary to do justice to the occasion. It is impossible to quote him now, but he played up on the contrast, quite ludicrous to him, between the world-war violence (the crashing of worlds, as he called it) and the odd spectacle of a man being really seriously interested in such an insignificant thing as an electron. This electron, by the way, was quite a busy sort of a particle even at that time. Since then it has enlarged its scope of activity enormously. Just a few months ago, Sir William Bragg, one of England's greatest physicists, in an address as president before the Royal Society, said: "It is not universally nor even sufficiently understood how important natural knowledge has become. It is true that in a vague way the nation is brought by the happenings of war to guess at the meaning of scientific research in every kind of enterprise. But still it would be difficult for most people to grasp the significance, much less the meaning of the description of a fact like this: that the R. A. F. could not carry out its operations without the knowledge resulting from the study of cathode-rays and electrons made by our physicists, which is equivalent to saying that by this time we might well have lost the war." A rather good showing for these extremely unassuming tiny particles! For the benefit of those readers who may have forgotten the fact, these cathode-rays are themselves simply streams of electrons.

This reference to application of the knowledge of the nature and behavior of electrons is only one of many that could be cited to illustrate the need and importance of basic research in physics.

HEREDITY AND TWINS

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THE value of twins as scientific material was recognized by Francis Galton, over half a century ago. In his book "Inquiries into Human Faculty" Galton tells of sending questionnaires to twins and near relatives of twins. He received returns in regard to thirty-five pairs, described as "extremely similar," and twenty pairs of extremely dissimilar twins. The members of the similar pairs were described as having almost identical hair and eye color, and about the same stature, weight and strength. Nine incidents were recorded of one member of a pair seeing his or her reflection in a mirror, and speaking to it in the belief it was the other member of the pair. Finger abnormalities were encountered in both members of three pairs, and nine pairs showed great similarity within pairs in regard to the onset and severity of illnesses. The following story is related in regard to one pair: "A was again coming home from India, on leave; the ship did not arrive for some days after it was due; twin B had come up from his quarters to receive A, and their old mother was very nervous. One morning A rushed in saying 'O mother, how are you?' Her answer was, 'No, B, it's a bad joke. You know how anxious I am!' and it was a long time before A could persuade her he was the real man."

The twenty dissimilar pairs, although reared together, showed great dissimilarities in size, general appearance, health and disposition. No one would suspect the members of these pairs as being even related.

Since Galton's time numerous investigators have worked with twins, and scientists have come to recognize that

the study of twins is one of our most valuable tools in seeking to unravel the interplay of heredity and environment in bringing about human variation. In recent years extensive twin data have been obtained by workers in Germany, Russia, England, Japan and the United States.

THE TWO TYPES OF TWINS

While of necessity circumstantial, the evidence is now convincing that identical twins and other identical multiple births consist of individuals who originated from the same fertilized egg cell or zygote. Fraternal twins arise from two different eggs fertilized by different sperms. Many years ago it was believed that identical twins arose from the fertilization of a single egg by two sperms, or "double fertilization." Our present day evidence, as we shall presently point out, gives no support to this idea.

Evidences of the two types of twins are obtained from both biological and statistical data. The occurrence of Siamese twins is analogous to the occasional appearance of double and conjoined individuals among lower forms. Direct observation of the various developmental stages is possible in many of these, and it has been shown that they invariably arise from a single fertilized ovum. Such double individuals are simply twins who have not completely separated. The nine-banded Texas armadillo almost invariably gives birth to quadruplets, always of the same sex. Studies of the embryos at various stages of development have revealed that the members of a set arise from the same zygote. This single zygote develops until about the period of gastrulation

before any separation occurs. At that time the embryo, which consists of a hollow sphere of cells, infolds, something like taking a hollow rubber ball and caving one side in. The embryo, at about this time, splits in two, and shortly thereafter the two daughter embryos again split, resulting in four individuals. The embryology of the armadillo is similar to that of man, and it is assumed that the formation of human identical twins occurs in much the same way. Of course, in the formation of twins, only one division occurs. If two successive divisions should occur, as in the armadillo, and one of the four daughter embryos again split, identical quintuplets would be formed. This is apparently the manner in which the Dionne quintuplets were formed. If an embryo should divide once and one of the daughter embryos divide again, identical triplets would be formed.

The human embryo is surrounded by two membranes, the amnion and the chorion. Twins of opposite sex, so far as has been recorded, are enclosed within separate chorions, and are called dichorionic. Like-sexed twins are sometimes dichorionic, and sometimes monochorionic, that is, both are enclosed in the same chorion. We should expect twins derived from the same zygote to be monochorionic, unless separation should occur after formation of the membrane. Likewise, we should expect fraternal twins to be dichorionics. Moreover, as males and females differ in their chromosomal makeup, we should expect identical twins to be like-sexed and fraternal twins to be in some cases unlike-sexed and in others like-sexed. The observations that monochorionic twins are like-sexed and that dichorionic twins are in some cases of the same sex and in others of the opposite sex are in harmony with what we might predict.

The statistical evidences are even more convincing than the biological evi-

dence. Sex in man is determined at the time of fertilization. If the egg is fertilized by a sperm bearing the X chromosome the new individual will be a girl, whereas if it is fertilized by a sperm bearing a Y chromosome, it will be a boy. As X-bearing and Y-bearing sperms are produced in equal numbers, the chances are approximately equal that any particular child will be a boy or a girl. Thus if all twins were fraternal we should expect to obtain approximately equal numbers of like- and of unlike-sexed pairs. It is similar to the fact if we were to toss two pennies simultaneously, we should expect 2 tails one-quarter of the time, 2 heads one-quarter of the time, and a head and a tail one-half of the time. But the ratio of like-sexed to unlike-sexed twins is more nearly of the order of 2 to 1, rather than 1 to 1. The excess of like-sexed pairs in the total twin population is to be expected if a sizable percentage is identical.

The blood groups and the M and N blood reactions are inherited in a simple, clear-cut manner. As we know the exact modes of their inheritance and the frequencies of the genes involved, it is possible to calculate how frequently sib pairs should be alike in both blood reactions. As fraternal twins have the same degree of genetic similarity as brothers and sisters, we should expect them to show the same percentage of concordance within pairs in the blood reactions as exhibited by sibs. Identical twins arise from the same zygotes, the members of each pair have the same heredity, and they should therefore show concordance in the blood groups. Hundreds of pairs of twins assumed to be almost certainly identical, on the basis of general similarities, have shown concordance in blood groups without exception. On the other hand, fraternal twins should show the same degree of intra-pair variation in the blood reactions as

found among brothers and sisters. Table I shows the results of the blood tests of twins investigated at two twin conventions.

TABLE I
INTRA-PAIR COMPARISONS OF BLOOD GROUPS AND
THE M AND N REACTION IN TWINS

	Assumedly Identical		Assumedly Fraternal	
	Calcu- lated	Ob- served	Calcu- lated	Ob- served
Alike ..	106	106	27.3	28
Unlike ..	0	0	42.7	42
Total ..	106	106	70.0	70

Identical twins show concordance in the appearance of clear-cut hereditary traits, such as color-blindness, hemophilia, albinism, baldness, polydactylism and syndactylism. The evidence is thus conclusive that identical twins have the same heredity, and are of monozygotic origin. If the old belief that identical twins were the result of double-fertilization of an ovum were correct, we should expect to find some degree of intra-pair variation in identical twins in the blood groups, the M and N reaction and other hereditary traits. This does not, of course, exclude the possibility that there may be a very small percentage of twins which arises by some third process, such as the double fertilization of an ovum, but there is no positive evidence that such a thing occurs.

DIAGNOSIS

Opposite-sexed twins are obviously fraternal. Likewise, twins showing marked intra-pair differences in features, body build, pigmentation, distribution of hair over the body, and head and ear shape may readily be classified as fraternal. If none of these characteristics shows enough difference to be conclusive, blood samples may be analyzed for grouping and M and N reaction. About 62 per cent. of fraternal twins (among North American whites)

will show some sort of intra-pair variation. In case the twins in question show the same blood reactions, the palm and finger-prints may be compared. If the intra-pair similarities are greater than the similarities of the two hands of either individual, the odds are about 19 to 1 that the twins are identical. Data concerning the fetal membranes at birth, that is, whether monochorionic or dichorionic, will give further evidence of zygosity. If dichorionic they are probably fraternal, and if monochorionic they are probably identical. This type of evidence is not completely conclusive, as there is good reason to believe that the separate chorions of fraternal twins may, in rare instances, fuse into one. Also, if identical twins should separate prior to the formation of the chorion, they would be dichorionic.

While it is possible, on the basis of any one of several criteria to positively recognize many twins as fraternal, there is no way to absolutely prove that the members of any particular pair are identical. We can, however, be reasonably sure that twins so similar as to be classed by relatives and friends as identical are actually derived from the same egg. This seems amply borne out by the fact that such pairs invariably have turned out to belong to the same blood groups and types. There is an occasional pair of like-sexed twins, perhaps one out of twenty pairs, where doubt may at first exist as to mode of origin. If none of the criteria we have mentioned indicates them to be fraternal, the odds are hundreds to one that they would not be so similar in all respects, unless they were derived from the same zygote.

In studies of approximately five hundred pairs of twins we have encountered five pairs concerning which serious doubt existed at first in regard to manner of origin. All were later demonstrated to be fraternal, three pairs on the basis of

intra-pair differences in the M and N reactions, one pair on the basis of great differences in the palm and finger-prints and the other pair on the basis of data revealing them to be dichorionic, and to have also had noticeable differences in hair and eye color at an earlier age.

HANDEDNESS

Left-handedness occurs more frequently in both types of twins than in the single born. About 7 per cent. of the single-born are left-handed, and close to fifteen per cent. of both types of twins. The higher percentage in both types of twins is principally accounted for by the large number of pairs composed of a right-hander and a left-hander. It was formerly believed that the high percentage of pairs showing differences in handedness was due to the fact that some pairs separated later in embryological development than did others. Those separating after the primordia determining the handedness of the individual had been established would consist of a right-hander and a left-hander, and would tend to be mirror-images of each other. They would be less similar in various respects than twins separating earlier in development, differing as do the right and left sides of a single individual. It was assumed that the high percentage of fraternal twins showing differences in handedness was partially due to too rigid a classification of identical twins, and the diagnosis of less similar identical twins as fraternal. According to that hypothesis, the less similar ones would include a high percentage of pairs comprising a right-hander and a left-hander.

Later work has shown the above hypothesis to be untenable. As pointed out above, in our own investigations doubtful cases have invariably turned out to be fraternal. Moreover, of the five cases later shown to be fraternal, three pairs consisted of a right-hander and a left-hander. There is no question

but that left-handedness occurs with about the same frequency in fraternal as in identical twins. Obviously, an asymmetry mechanism or mirror-imaging can not explain the phenomenon in fraternal twins. The explanation must lie in something which both types of twins have in common, as contrasted with the single born. In all probability conditions before birth, peculiar to twins, such as crowding and position in the uterus must be responsible.

Investigations have shown that twins showing intra-pair differences in handedness are about twice as likely to have left-handers among their immediate relatives as are pairs consisting of two right-handers (Table II). This would seem to

TABLE II
CORRELATION OF HANDEDNESS OF TWINS WITH HANDEDNESS OF RELATIVES

	Identical Twins		Fraternal Twins	
	R-R	R-L	R-R	R-L
Without left-handed relatives	105	25	84	12
With left-handed relatives	28	22	16	15
Total	131	47	100	27

indicate that right-handed pairs are more strongly inclined towards right-handedness by hereditary make-up than are those pairs showing differences in handedness. In other words, the handedness of twins is determined both by genetic make-up and by conditions before birth. The effectiveness of conditions *in utero* in determining handedness depends to a large extent upon the genotype of the twins.

THE TWIN METHOD OF RESEARCH

Several scientists have made use of twins in investigations of heredity and disease. In 1936 an important investigation of tuberculosis in twins was completed by Diehl and von Verschuer of Germany. As shown in Table III, about 25 per cent. of fraternal twins and 80

TABLE III
CONCORDANCE IN INCIDENCE OF TUBERCULOSIS*

	Concordance	Number of Pairs
Identical	80 per cent.	80
Fraternal	25 " "	116

* Karl Diehl and O. F. v. Verschuer. *Zwillingstüberkulose II.* Jena, verlag von Gustav Fischer, 1936.

per cent. of identical twins showed concordance in the incidence of the disease. By concordant pairs we mean those in which both members were affected, and by discordant those pairs in which only one member showed the condition. Any discordance within identical twins can not be due to heredity, and must therefore be ascribed to environment. Fraternal twins receive, on the average, half of the same hereditary material, and their greater discordance, as compared with the identicals, is assumed to be due to hereditary differences. Let us use A to symbolize the part played by heredity, C concordant pairs, D discordant pairs, i identical and f fraternal twins. The part played by heredity in bringing about variation in fraternal twins may be estimated as follows: $A_f = \frac{C_i - C_f}{D_f}$. Ac-

cordingly, about 73 per cent. of the variations in fraternal twins in regard to the incidence of tuberculosis may be considered to be due to genetic factors. Table IV summarizes the results of various

TABLE IV
CONCORDANCE OF TWINS FOR SEVERAL TRAITS

	Identical		Fraternal	
	C	D	C	D
Chin dimple	27	2	15	17
Cheek dimple	18	5	15	8
Eye epicanthus	14	0	4	6
Whooping cough	98	4	63	13
Hernia	24	15	0	6
Measles	179	10	127	19
Rachitis	20	2	6	20
Cancer	29	24	13	22
Epilepsy	32	21	4	123
Schizophrenia	28	13	15	86
Crime	45	21	32	52

studies of concordance and discordance in twins.

It is hazardous to draw sweeping conclusions regarding the relative potencies of heredity and environment on the sole basis of twin data. Twins of both types differ from the single born in having a unique prenatal environment. Position in the uterus, crowding, imbalance of the blood supply and more difficult circumstances at birth appear to play important parts in the determination of some traits.

The post-natal environment of fraternal twins reared together is more similar than that of sibs reared together. They are contemporaries, go to the same school, have the same teachers and playmates, and share more experiences. The importance of this type of environmental difference varies, depending upon the trait in question. For most physical traits and disease resistance, there is little reason to suppose it is important. It should not be overlooked, however, in the investigation of intelligence and personality traits. As fraternal twins and sibs have, on the average, the same degree of genetic similarity, differences in the degree of concordance for any traits must be due to environmental factors. Let us allow B to represent such environmental differences and s to represent sibs. Then $B_s = (C_f - C_i)/D_s$.

Unfortunately, investigations usually include only data from the two types of twins, and none concerning sibs. When sib comparisons are included, the value of the data is greatly enhanced. This is well illustrated by the data on feeble-mindedness in twins and sibs, collected by Rosanoff *et al.*, shown in Table V.

TABLE V
CONCORDANCE AND DISCORDANCE IN TWINS AND PAIRED SIBS FOR MENTAL DEFICIENCY.
DATA TAKEN FROM ROSANOFF*

	No. Concordant	No. Discordant	Per Cent. Concordance
Identical Twins ...	115	11	90.9
Fraternal Twins ...	128	112	46.6
Sib pairs	716	142	16.5

* A. J. Rosanoff, L. M. Handy and Isabel Rosanoff Plesset. *Psychological Monographs* 216, 1937, Psychological Review Company, Princeton, N. J.

The part played by heredity in bringing variation may be estimated by the following formula:

$$A_s = \frac{C_i - C_s}{D_s} - \frac{C_f - C_s}{D_s}.$$

Thus, about 54 per cent. of the variation in sibs in respect to mental deficiency may be attributed to heredity. But suppose no sib data were included. Then we should have to rely on twin data, and using the formula $A_f = (C_i - C_f)/D_f$, we should find A_f to equal 82.7 per cent. Or, suppose the data included only identical twins and sibs, then we should have to estimate the part played by heredity on the basis of $A_s = (C_i - C_s)/D_s$, which equals 90.3 per cent. In either case, the environmental forces operating to produce differences between sibs and fraternal twins can not be estimated, and the part played by genetic factors is greatly over-estimated.

The concordance-discordance method of twin research is necessarily confined to qualitative traits. It permits only two classifications, those who possess the trait, and those who do not. Variable traits, such as size and intelligence, showing quantitative variations, must be treated in a different manner. Intra-pair correlations, symbolized by r , are substituted for C and D . Thus $A_f = (r_i - r_f)/(1 - r_f)$, and

$$A_s = \frac{r_i - r_s}{1 - r_s} - \frac{r_f - r_s}{1 - r_s}.$$

Newman, Freeman and Holzinger recently completed an investigation of certain physical, mental and personality traits of 50 pairs of fraternal twins reared together, 50 pairs of identical twins reared together, and 19 pairs of identical twins reared apart. Table VI shows the part played by heredity in determining variation in fraternal twins in each of several traits. Comparisons of identical twins reared together with identical twins reared apart give a basis for estimating the role of post-natal environment in producing differences.

TABLE VI
THE PERCENTAGES OF VARIATION IN SEVERAL TRAITS IN FRATERNAL TWINS ESTIMATED TO BE DUE TO HEREDITY. DATA TAKEN FROM NEWMAN, FREEMAN AND HOLZINGER*

	A_f		A_f
Standing Height	81	Binet I Q	68
Sitting Height	76	Otis Score	77
Weight	78	Otis I Q	80
Head length	78	Word meaning	68
Head Width	75	Arithmetic computation	72
Cephalic index	75	Nature study and science	34
Finger ridges	90	History and literature	45
Binet Mental Age	65	Spelling	53

* Newman, Freeman and Holzinger, "Twins: A Study of Heredity and Environment," University of Chicago Press. 1937.

Table VII shows such an estimate for seven traits, as contrasted with estimates of the amount of variation in fraternal twins reared together attributable to environmental factors. It would be enlightening to know what the values of these environmental factors would be if identicals reared apart were compared with fraternal twins reared apart. It is quite clear, however, that the relative parts played by heredity and environment depend both upon the type of environment and on the genotype of the individual.

It should be kept in mind that fraternal twins have, on the average, half of the same heredity. If we are interested in determining how much of the variation in respect to a given trait in the general population on the average may be attributed to heredity, comparisons of both types of twins, reared apart, paired sibs reared apart, and unrelated pairs

TABLE VII
PERCENTAGES OF DIFFERENCES IN CHARACTERS DATA TAKEN FROM NEWMAN, FREEMAN AND HOLZINGER, LOC. CIT.

	Variations Due to Post-Natal Environment	Percentages of Variations in Fraternal Due to Environment
Height	24	18
Weight	87	21
Head length	19	24
Head width	58	32
Binet I Q	59	31
Otis I Q	64	16
Stanford Achievement	87	36

reared apart should give us a fair estimate. Let us use u to symbolize unrelated pairs, and let us further assume that all of the pairs included in the following formula have been reared apart. Then

$$A_u = \frac{r_1 - r_u}{1 - r_u} - \frac{r_1 - r_2}{1 - r_2}.$$

DISCUSSION

The results of various investigations of twins have emphasized the fact that the relationship between heredity and environment in the determination of variability in man is not fixed or static, but rather dynamic. That is, the relative parts played by each depend not only upon the trait under consideration, but also upon prenatal and post-natal environmental conditions and the genotype of the individual.

Most of the scientific work with twins has to date been primarily concerned with cross-section comparisons of the occurrence and degree of certain traits in twin populations. A barely touched and perhaps even more important phase of twin investigation is that of continuous studies of identical twins from birth through childhood and maturity. This should be especially enlightening in regard to growth rates, metabolism, disease resistance, intelligence and personality. The members of a pair could compare as to the effects of different diets, different types of exercises, and even different types of training in schools, on mental and physical development. It would also be feasible to compare identical twins reared together until maturity, and later to determine what changes might be brought about as a result of living in different environments and engaging in different occupations.

As identical twins have the same genotypes, any intra-pair differences must be due to either prenatal or post-natal environmental factors. Thus identical twins offer material *par excellence* for

measuring the effectiveness of various types of environment and training. Fraternal twins, when compared with sibs, enable us to evaluate the unique environmental influences associated with both types of twins. Fraternal twin data, like sib data, may also enable one to determine whether or not a trait is inherited in a simple manner.

Many of the most conspicuous and interesting variations in man are undoubtedly due to a large number of genes, acting in such a variety of manners as to defy simple, clear-cut analysis. Furthermore, many such traits are conditioned to a considerable degree by environment. Especially does this seem to be true in mental and personality traits, general growth processes, vigor, longevity and disease resistance. The study of twins is the key to the solution of the relative roles of heredity and environment in the determination of variation in such traits. Twin research has only begun, and to be of greatest value it should be conducted on a much larger scale than has ever been attempted. Probably no single institution could do this alone, but many universities, hospitals, and other agencies working under a unified plan could go far in unraveling the interplay of heredity and environment in human development. This type of research would call for specialists in genetics, statistics, medicine, dermatoglyphics, psychology, blood, nutrition, endocrinology, embryology and various other related fields. Research with twins has to date been done largely by isolated workers who have been able to devote only part of their time to it. There is a definite need for some sort of a central or national association devoted to research with twins which could act as a clearing house for twin data and their interpretation. It is hoped that some such comprehensive and large-scale research with twins may be inaugurated in the not too far distant future.

PHARMACOLOGIC SHOCK TREATMENT FOR MENTAL DISEASE¹

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IN 1922 the medical and lay world was electrified by the announcement of Drs. Banting and Best that they had succeeded in isolating insulin, and thereby had made possible the effective treatment of diabetes. This opened an entirely new hope to sufferers from the disease, which in its severer forms had been invariably fatal. Since then, thousands of lives have been prolonged, and hundreds of thousands of people who formerly had been doomed to severe invalidism have been enabled to lead a practically normal existence. Fittingly, the discoverers of insulin were awarded the Nobel Prize in Medicine. In 1937, fifteen years later, the American medical and lay world was electrified by the announcement of Dr. Sakel that this same preparation, insulin, when used in an entirely different manner, had proved to be a remedy of hitherto unheard-of effectiveness against that most common and usually hopeless form of insanity, dementia praecox. Conservative physicians and psychiatrists greeted Dr. Sakel's pronouncement with considerable skepticism. They recalled with distaste other much publicized and ultimately discredited "cures."

And there were good reasons for this incredulous and even skeptical attitude. It had been easy for physicians to accept Dr. Banting's recommendation of insulin treatment for diabetes, since it had long been known that this disease was due to a lack of insulin production in the patient's body, and Drs. Banting and

Best, after developing a practical means for the extraction of insulin from animal tissues, merely did the rational thing in satisfying this lack. In the case of dementia praecox, however—the cause was unknown—Dr. Sakel had developed his treatment simply by boldly following up a hunch, and there was no theory available which would sensibly explain its effectiveness. Dr. Sakel was not a formally trained psychiatrist, and, consequently, one wondered how authentic his original cases might have been, and how valid his determination of a "cure." His work had all been done in Europe (Vienna), and undoubtedly the criteria governing diagnoses there are more flexible than in the English-speaking countries. But, as confirmatory reports, first from England, and then from research centers in this country, continued to pour in, the skepticism began to be replaced by feelings of wonder and something of awe, as physicians began asking incredulously, with fingers crossed—Is it true that there is a new hope open for those facing the terror of being overwhelmed by the flood of madness?

For mental illness in many of its phases may well be compared to a flood. The overwhelming of a smoothly functioning mind by unusual mental and emotional strains is quite analogous to a smoothly flowing river which has become overburdened by torrential rains, and burst its banks. If the banks are high and well buttressed, composed of stout clay or rock, when the flood subsides the river will return to its usual channel. Similarly, when mental illness develops in an individual with a sound

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heredity and previously stable personality, not undermined by any ravaging physical ills, we expect the mind's activity to return to normal rational channels when the excessive stresses and strains have passed. On the other hand, when the river's banks are low and sandy, built of crumbly materials, we are not surprised at the flood leaving behind it many permanent aberrant channels and, at times, even diverting the main stream itself to an entirely new course. Likewise, a mental breakdown developing in a shallow, brittle personality with a tainted hereditary background is more than likely to persist as a chronic form of insanity, with the streams of thought and action permanently diverted into bizarre and irrational pathways. The analogy of mind and river may be drawn still further—for instance, certain pathologic, sluggish, depressed mental states remind one of a proud stream which has dried up to a mere trickle after a prolonged period of heat and drought.

Bearing this analogy in mind, it becomes apparent that the problem of mental illness, as of flood control, may be attacked along three main lines: first, preventive—lessening the volume of emotional and mental strains to which the individual is exposed, much as the engineer builds dams at strategic points and promotes reforestation projects; second, therapeutic or reconstructive—attempting to bolster up and repair the weakened or broken banks of the personality, analogous to the piling up of levees at the weak points of the river; third, eugenic—attempting by sterilization and segregation to prevent the propagation of the mentally unfit or "fragile" personalities—a course which in the present state of knowledge is quite uncertain—which offers little solace to the current generation of sufferers and their families, and which is generally repugnant to a humanitarian society. This last measure is comparable to the abandonment

as uninhabitable of otherwise desirable and fertile river bottoms, particularly in view of the fact that the aberrant personality strains which supply us with most of our insane are also known to furnish a considerable percentage of our geniuses.

Consequently, to the practising psychiatrist it is still the second line of attack which is of primary importance. He is always placed in a trying position whenever a new method of treatment of any promise is introduced and, as is invariably the case, publicized in the lay press in an over-enthusiastic, extravagant and distorted manner. This has particularly been the case in the past couple of years with the insulin and metrazol treatments for insanity. Lay writers on medical subjects have an inveterate compulsion to overemphasize successes and to gloss over or neglect to mention failures or limitations. The psychiatrist is confronted day after day by relatives of mental patients whose interest and concern has been stimulated by what they have heard or read, and in whose minds the following questions are paramount:

(1) What is meant by the insulin and metrazol treatments? What types of cases may be benefitted by these treatments, and how much benefit may be expected?

(2) What are the dangers connected with these treatments?

(3) What hope is there for the other cases?

In the following pages we shall endeavor to give an adequate and accurate answer to each of these questions. Thus, we hope to make available to the public a conservative picture of what has been and may yet be accomplished.

(1) What is meant by the Insulin and Metrazol Treatments for Insanity?

Before proceeding with the answer to this question, it is necessary that the reader have some idea of the nature of

the diseases or illnesses these treatments are supposed to benefit. Insulin treatment has been recommended primarily for certain types of dementia praecox. Metrazol treatment has yielded encouraging results in certain depressed and stuporous states.

Dementia praecox is a rather broad term used by psychiatrists to group together several more or less related forms of mental disease in which the outlook for complete recovery is more or less unfavorable. There are approximately one million hospital beds maintained in the United States. Almost one half of these (some 47 per cent.), are constantly occupied by cases of mental illness. More than half of the mental cases (probably 60 per cent.) constantly hospitalized belong to the dementia praecox group. Psychiatrists generally recognize four distinct forms of dementia praecox, which they designate as—simple, catatonic, hebephrenic and paranoid types. The characteristic symptoms of each form, briefly, are as follows:

In the simple types the outstanding symptoms are a marked lack of emotional attachment to the ordinary, so-called normal things, about which people are much concerned. There is apt to be a lack of interest in what is going on about them or in the world—a lack of affection for their near relatives or friends—utter lack of ambition or initiative. There is no real sadness, only apathy and indifference. Such patients do not read the newspapers or listen to the radios; they might be domiciled in a ward for years without bothering to learn or remember the names of any of their fellow-patients, their nurses or attendants. They show no worry or concern over illness or any other misfortune involving their family or friends. They tend to remain inert, though if urged sufficiently will usually follow the path of least resistance and occupy themselves in simple tasks. They never com-

plain of anything bothering them, and often will permit physical illnesses to become far advanced before calling anyone else's attention to them. If some privilege or prerogative is denied them, they do not fret or fume, merely accept the denial listlessly. Nothing seems important enough for them to expend any effort to attain. They lead what is called a "vegetative" existence—eating, sleeping, excreting—and displaying little if any enthusiasm in any of these functions. The simple types of dementia praecox comprise only a very small percentage of those cases which come to a mental hospital, which is fortunate, since they do not respond favorably as a rule to the new treatments we are discussing.

The hebephrenic forms are the most numerous encountered in hospital psychiatry. These patients show characteristically the childish, silly, bizarre speech, mannerisms and behavior which popular fancy considers the hall-mark of insanity. They are apt to bear continuously a silly, insipid expression, show peculiarities of dress, often decorate themselves with all sorts of gewgaws; they are often observed grimacing and talking to themselves rapidly and incoherently, and on closer observation it appears that they are responding to "imaginary" voices. It is evident that they are preoccupied with silly fantasies, and they too have lost interest in the real things which are going on about them in their daily life and in the outside world. This lack of interest becomes reflected as the disease progresses in an increasing lack of knowledge and loss of what has formerly been learned. They may exhibit delusions or false ideas of grandeur or of persecution, but express little concern about these delusions, and do not bother to elaborate any remotely logical explanation of their ideas. They often complain of bizarre bodily feelings or sensations, and may imagine they are suffering from all sorts of fantastic and

impossible physical ailments, that some or all of their vital organs are missing, diseased, or dead, or that various kinds of machines, mechanisms, animals or persons have taken residence in their bodies. Patients of this group also do not as a rule respond favorably to the new treatments.

The paranoid forms comprise the second most numerous group of dementia praecox patients. These individuals usually present a rather normal appearance to the uninitiated. They carry themselves well, are careful about their dress, clean in their habits, and generally they show a fairly well-preserved intellectual capacity. They have become, however, imbued with the idea that they are superior persons and that, consequently, others are jealous of them, and are constantly striving to degrade and take advantage of them. They manifest an air of arrogance, haughtiness or martyrdom. They feel that they are surrounded by jealous enemies who are constantly plotting against them, poisoning them, talking about them. Often they hear imaginary voices cursing, threatening, deriding them, accusing them of unspeakable thoughts and actions. They usually construct a superficially logical theory to explain why they are the objects or victims of these persecutions. Not infrequently they react violently against persons who are in the vicinity, who they imagine may be connected with their persecutors. Such cases are frequently benefitted by the new treatments.

The catatonic forms are characterized by an extremely bizarre group of symptoms. These depend largely upon what basically seems to be a blocking of thought and action, a sort of inertia which causes the patients to persist in definite forms of activity or inactivity. These include a marked tendency to definite types of stuporous states in which the patients will sit, stand or lie

in fixed postures or attitudes for weeks or months on end. In these stupors their eyelids usually are closed (though an extremely rapid "nervous" flickering is common); they do not speak or respond in any way to questioning, yet it is evident that they are aware of what is going on about them. In the deeper forms of stupor they may make no effort to feed themselves or to attend to the calls of nature. Frequently, starvation may be avoided only by forced feedings with a stomach tube. Often a condition known as "waxy flexibility" is shown. Into whatever constrained or awkward position or posture they may be placed, they will tend to remain, exactly as if their bodies were made of some inert wax, instead of living nerve, muscle, and bone. Again they may show "stereotypy," repeating interminably some particular apparently meaningless movement or gesture which may have been suggested to them by others, or, more usually, is a symbolic expression of their own mental complexes. Similarly, they may repeat interminably specific words, phrases, noises or figures of speech. In contradistinction to these stuporous, automatic and passive states, they may have periods in which they are wildly excited, extremely overactive, impulsive, destructive and assaultive, and may further manifest marked tendencies to mutilate or destroy themselves. At such times they are prone to be actively hallucinated, and will rant on noisily against the "voices" they hear berating and threatening them. Strange as it seems, it is just these most dramatic and obviously abnormal types of dementia praecox, which are more apt than the others to have periods of definite normality and mental lucidity. And perhaps because of this natural tendency for "partial remission," a goodly proportion of "catatonic" patients will respond favorably to insulin and metrazol treatments.

Thus, in summing up the four basic types of dementia praecox which we have just discussed, it is clear that the psychiatrist does not anticipate favorable results from treatment when dealing with the simple and hebephrenic types, while he is much more optimistic when dealing with the paranoid and catatonic forms. A review of our original analogy of the mind and the river may clarify to some extent the reasons for this distinction. The simple type of dementia praecox may be compared to a river in which the springs of its *source* have dried up, so that an insufficient volume of current is left to sustain the former amount of industry and navigation. There is no way in which engineering can restore such a stream to enable it to assume its former functions. The hebephrenic type of dementia praecox may be compared to the river with crumbling, sandy banks all along its course. After a major disastrous flood, its originally weak walls have been washed away and broken down in so many places—so many new aberrant channels have been developed, that it is an impossible task to restore it entirely to its former course. The paranoid type of dementia praecox may be compared to a stream whose banks have only a few weak points which have been broken through. It is possible to plug these breaks and to fortify the levees sufficiently so that the normal course is restored. Finally, the catatonic type of dementia praecox may be compared to a river, which has been dammed up near its source by some natural catastrophe such as an avalanche. The original channel remains intact, and once the dam has been blasted away, the river promptly resumes its normal course. To be sure there may be an initial period of turbulent flood (the catatonic excitement), when the dam is first broken through, but after this has subsided the well-grooved channels of the personality

will maintain a directed and productive flow.

At this point we must add that in very many instances, the situation is not nearly so simple as we have indicated in the above remarks. Many clinical cases of dementia praecox which we see are by no means "pure" as regards their type. They present varying admixtures of features characteristic of two or more of the types. Thus a case which is predominantly paranoid or catatonic may also manifest many hebephrenic features. Consequently, it is extremely difficult if not impossible to predict in such cases what the outcome of treatment may be. Moreover, when the illness is but newly established, the specific type is usually not well defined, and it is very common to see a case, which in its beginnings seemed to belong to the higher paranoid or catatonic categories, ultimately "regress" to the lower hebephrenic or simple forms. In fact, it is this tendency toward "regression" which many psychiatrists feel is the chief argument supporting the theory of essential unity of the disease complex called dementia praecox. It is consistent with this characteristic of the disease that all workers in the field have found that the percentage of good results in all cases treated varies inversely as the duration of the illness up to the time treatment was first instituted. In other words, the treatment to be effective must be applied before the process of regression has become marked, that is, before the disease has become crystallized in one of its lower, resistant forms. Thus, few workers are inclined to be optimistic in treating cases which have been sick over two years, and many workers feel that treatment in chronic cases is entirely futile. As a working hypothesis, however, it may be assumed that in those cases presenting mixed features, improvement may be obtained mainly in those symptoms which are not character-

istic of the regressed types of the disease.

We are now ready to describe briefly the major details of the new treatments. The treatments are strenuous and rigorous and, consequently, before they are administered every precaution must be taken to put the patients in as good physical condition as possible. In the insulin treatment, the patient is given injections on successive days of increasing doses of insulin early in the morning, before he has had anything to eat. As the proper dose is reached the patient goes through a stage of increasing drowsiness, followed by a stage of progressive loss of muscle control, followed by a stage of unconsciousness or coma. The sequence of events is quite similar to that produced by the induction of an anesthesia, as with ether. But, while an anesthetic like ether is a poison which acts by "doping" the nerve centers, insulin is a natural gland secretion which progressively diminishes the nerve center activity by removing sugar from the body tissues and nutrient fluids. Nerve activity needs this sugar since it is the only fuel which nerve cells can utilize as a source of energy; consequently, as the tissue sugar is removed the nerve-cell activity (technically called its metabolism) is progressively diminished. It has been found most advantageous to allow the insulin activity to continue for about four hours at a session. The usual course of treatment consists of fifty such sessions, administered five or six mornings a week. Thus the average course of treatment lasts about ten weeks, during which time the patient receives special nursing and dietary care. A specially trained physician must be at hand during the entire period of "coma," since he must be instantly available to take care of any untoward complications which may appear. It is this absolute requirement of extra, specially trained personnel, whose entire

energies must be devoted to giving the treatments, which makes it so expensive and so difficult to incorporate in limited and curtailed mental hospital budgets. The expense of the cost of the insulin used is only a very minor item.

Each session of "coma" is terminated, that is, the patient is "awakened," by replacing the sugar which the insulin has removed from the tissues. This is done by instilling the proper amount of sugar solutions into the stomach (usually by a rubber stomach tube), or, where a more rapid "awakening" is desired, by injecting sugar solution directly into the blood stream. When the insane patient first awakens, he often shows an increased mental clarity or lucidity which may last only a few minutes. In those cases which show permanent improvement from the treatment, this "lucid interval" usually becomes progressively prolonged as the treatment is continued, until ultimately the patient is "lucid" all the time and is "insane" no longer.

About the time Dr. Sakel was reporting his first outstanding successes with the insulin treatment, a Hungarian psychiatrist, Dr. Ladislaw von Meduna, began working intensively with an entirely different type or drug, called metrazol. Dr. von Meduna felt that there was some sort of natural antagonism between the nervous disease epilepsy, and those nervous diseases grouped together under the term dementia praecox. Consequently, he felt that if one could imitate the outstanding symptom of epilepsy, the epileptic convulsion, in dementia praecox patients, one might favorably influence the course of their illness. He experimented with various drugs which were known to have convulsive effects on lower animals, and finally decided upon "metrazol," a synthetic chemical related to camphor, as the safest and most practical. He then tried out his artificially induced convulsions on humans

and his initial results were at least as spectacular as Sakel's. The von Meduna treatment consists simply of the injection into the vein, of a sufficiently large dose of metrazol to produce a generalized fit or convulsion. The convulsion is an extremely violent one, and resembles the natural epileptic convulsion in its broad outline, though not in its detailed mechanism. It is usual to give three such convulsions a week, and to give a total of ten to twenty convulsions in the average case. The convulsion itself lasts from three fourths of a minute to a minute and a half, is followed by a state of coma or complete unconsciousness lasting a few minutes, and finally by a state of confusion or befogged mental activity which may last a couple of hours. After these phases of the metrazol effect have worn off, the patient is apt to show a state of unusual mental clarity with freedom from his psychotic symptoms, very similar to the "lucid" intervals noted after emergence from insulin coma. Again, when the treatment is successful these lucid intervals become progressively prolonged until ultimately all of the picture of insanity is pushed to the background. It soon became apparent that the metrazol treatments appeared to benefit, by and large, basically the same classes of patients as the insulin treatment, with a tendency for greater success in the catatonic and stuporous groups. It also became evident that while one was likely to obtain a more rapid improvement with metrazol, the improvement was more likely to be maintained for a prolonged period when insulin was used.

Very early in the course of his experience with the insulin treatment Dr. Sakel found that a certain proportion of his patients tended to have convulsions during the course of insulin coma. He further noted that certain of these patients were prone to show a much more rapid gain in their improvement

after such convulsions. As a result of these observations, he found it advisable to supplement his original insulin treatment in selected cases by artificially inducing convulsions during certain phases of insulin coma. He too chose metrazol as the most practical drug for this purpose. This "combined" insulin and metrazol treatment has also become an accepted technique with most workers in the field.

We are now ready to consider what the verdict of time and experience has been as regards these new approaches to the problem of mental disease. Three years have elapsed since these treatments were first introduced to this country, and thousands of cases have been treated during this interval. Scientifically minded physicians will discount any claims of therapeutic achievements unless they can be convinced that a sufficiently large number of cases have been treated, and that the results have been adequately checked and "controlled." By this they mean that they expect a large number of cases which have been treated by the new methods, to be compared with an *equally large number of similar* cases which have been treated by the old methods, and that the comparative results be evaluated after a sufficiently long period of time has elapsed. It would seem that these conditions have been met in the New York State Hospital System. Dr. Benjamin Malzberg, senior statistician of the New York State Department of Mental Hygiene, and Dr. John R. Ross, superintendent of Harlem Valley State Hospital (where Dr. Sakel inaugurated insulin treatment in this country), have recently collected and summarized the results obtained in the New York State institutions. They compared 1,039 patients treated with insulin with 1,039 patients of essentially similar characteristics who had received only the usual types of hospital treatment. They found that

almost two thirds of the insulin-treated cases showed a significant degree of improvement (65.4 per cent.), and 12.9 per cent. of the total were considered recovered. In the control group only 22.1 per cent. showed a significant degree of improvement, and only 3.5 per cent. were considered recovered. Thus, it is evident that when insulin was used a favorable outcome was obtained three times as frequently as when it was not used. These figures are further substantiated in that in a summary of 718 additional cases treated with insulin, practically the same percentages of improvement and recoveries were maintained.

As regards the results of metrazol treatment, quite a different picture is seen. Dr. H. M. Pollock, of the New York State Department of Mental Hygiene, has summarized the results of metrazol treatment on a series of 1,140 dementia praecox patients. Of this group he found that only 1.6 per cent. were considered recovered, while only 36 per cent. showed some degree of improvement. These statistics when compared with those given for the control group would seem to indicate that on the whole metrazol treatment is definitely not worth while. Practically everyone who has worked intensively in this field, however, has encountered certain cases which responded only indifferently to treatment with insulin alone, yet showed a spectacular improvement when metrazol was used in addition. Perhaps the metrazol figures suffer by comparison simply because the great preponderance of cases treated were not of the catatonic, stuporous types which are most amenable to the convulsive method. Another, more potent argument against the indiscriminate employment of metrazol is the rather frequent occurrence of serious physical complications which we will mention below. In passing, we might mention that in recent

months exceptionally favorable results have been obtained with the use of metrazol in certain chronic depressed mental states, not belonging to the dementia praecox group of illnesses. It may well be that ultimately metrazol treatment will find its chief sphere of usefulness in such new fields.

(2) What are the dangers and possible untoward reactions which may be associated with these treatments? In describing the insulin method, it will be recalled, we compared the development of insulin coma to the phases of administration of an anesthetic. If we bear this in mind, we can readily understand how the dangers of insulin coma are comparable to those of a period of deep anesthesia. Most of us can remember how with years of experience and refinements of technique the dangers and, consequently, the dread of anesthesia have been progressively diminished. Similarly, with insulin coma, as our experience has widened and our procedures have become perfected the dangers have lessened and our fears have diminished. Now, in any state of unconsciousness or coma the possibility exists that the patient may aspirate (or inhale) fluids or secretions from the mouth or upper air passages into the lungs, and such aspirations are likely to lead to a severe inflammatory condition or "pneumonia." In the old days when the methods of administering anesthesia were still rather crude, such "ether pneumonias" were rather common. Nowadays, these complications are so rare that the term "ether pneumonia" is practically obsolete. Likewise, in the earlier days of insulin-shock treatment "aspiration pneumonias" were fairly common, while lately as techniques have become progressively refined and workers have become more expert, the incidence of this complication has markedly diminished. Another serious, but fortunately, rare complication which may be

encountered is that called "prolonged" or "irreversible" coma. In this condition, the patients fail to awaken as they should, soon after the usual means of restoring the blood-sugar level have been employed. Recent studies by Dr. J. Wortis and R. H. Lambert from the Phipps Psychiatric Clinic of the Johns Hopkins Hospital, have indicated the causative factors for most of these mishaps, and have indicated satisfactory measures for preventing and treating them.

A concrete idea of the actual mortality risk associated with the insulin-shock treatments may now be secured by reviewing Dr. Malzberg's statistics from the New York State Hospital Service. In 1,039 patients who received insulin treatment there were thirteen deaths. On the other hand, in the control untreated group of an equal number of comparable patients, there were forty-eight deaths. From these figures it would seem that patients selected for the insulin treatment had more than three times as good a chance to survive the first few years of their mental illness as their less favored companions. While it is appreciated that the insulin-treated cases constitute a physically select group, it must also be borne in mind that when insanity is permitted to run its natural course unmolested, it frequently leads to inroads in the physical health of the patients and consequently reduces their resistance to bodily illnesses and infections. On the other hand, when insulin treatment has been used the patients have invariably gained much weight and have shown considerable improvement in their physical status, even in those cases where no worth while restoration of mental function has been obtained.

With metrazol treatment we must reckon with a considerably higher proportion of hazards and untoward reactions, even though the general mortality

rate is not significantly higher than in the case of insulin. From the humanitarian standpoint, metrazol treatment is decidedly inferior since many patients find it exceedingly unpleasant and in many cases overwhelmingly terrifying. For the most part, however, these feelings of terror may be obviated by using the combined metrazol and insulin method. More important is the occurrence in occasional cases of fractures and dislocations of certain long bones of the extremities. These complications are the result of the uncontrolled violence of the metrazol convulsion, a factor which can hardly be eliminated since it is generally agreed that it is the convulsion itself which produces the desired curative result. There have also been a few isolated instances reported of sudden death following a metrazol convulsion due to paralysis of breathing or heart failure. Such fatalities also seem unavoidable, since any form of generalized convulsion (of the epileptic or other natural types), entails the same possibility. A more hopeful outlook has developed as regards the "pneumonias" and "lung abscesses" which have been known to complicate occasional cases undergoing metrazol treatment. Dr. M. Zeifert, of the Brooklyn State Hospital, has recently demonstrated that this type of complication is generally caused by the injection of the drug introducing minute blood clots into the circulation, and he has devised a simple, effective method of preventing this. Finally, it has been found that a certain proportion of metrazol-treated cases may show minor evidences of damage to the bony elements of the spinal column, as disclosed by x-ray studies. While for the most part these spinal column changes do not seem to cause clinical symptoms, these findings have naturally led to increased caution and conservatism in the use of metrazol. Means are now being

developed which will probably prevent these changes in the future. In the meantime, in view of this list of complications it would seem the part of wisdom to employ metrazol only in those cases which seem to offer a reasonable prospect of improvement.

(3) In conclusion, what hopes can we hold out for the chronic cases of dementia praecox—those which we have found are to a great extent not amenable to these new forms of treatment? As regards recent cases, it is clear that we can readily agree with Dr. Malzberg, who wrote “. . . it appears permissible to draw comfort and encouragement from the present results. No longer need families feel the anguish and despair that come from the thought of an incurably stricken relative. It is necessary, however, to reiterate the pressing need of early diagnosis and treatment, and this requires the intelligent cooperation of the public with hospital authori-

ties . . .” It is equally clear that we have only begun to scratch the surface of the problem of these forms of insanity. What further research and experiment along these lines will uncover, it is impossible to predict. Certainly, since these initial steps have been taken, we can anticipate an accelerated rate of progress. Even in our most advanced chronic cases we are now accustomed to see interludes of mental clarity when they are under the influence of insulin and metrazol. Does not this indicate that we are dealing with a correctible disorganization of function and not an irremedial destruction or alteration of structure? We have become reoriented to the problem. From an attitude of hopeless fatalism we have been converted to one of optimistic resourcefulness. With this change of attitude it seems inevitable that more and more effective tools will be devised to return the wayward mind to its normal track.

EDUCATION

WESTERN civilization has for more than two thousand years sought to establish a rigid separation between reason and emotion, between “objectivity” and “values.” The material fruitfulness of the separation in the past is the chief reason for its uncritical acceptance in the present. The intellect, however, is not simply an aspect of human life—and a superior aspect in typical Aristotelian tradition—but it arises out of the emotional and ethical life, is deeply rooted in it, and draws its strength and stamina from it. The moral and emotional bleakness of typical intellectual communities, and many of the characteristic problems of the American college and university can only be understood in the light of the persistence of this tradition. When we discuss our “problems of teaching” and set large staffs at work on the problems of “youth” and “teacher’s training,” we are simply tracing some of the symptoms of a malady that is rooted in this distinction of reason and emotion that underlies most of our thought about the entire educational process. . . .

Occasionally, a teacher in the humanities or the social sciences will venture the statement that the “relations” of subjects or the “meaning” of the learning is the heart of good teaching, but beyond that point few will risk themselves lest they be accused of “preaching.” So

—in the language of the Sermon on the Mount—while the young clamor for bread, we continue to offer them stones, and of the discontent of the young provokes critical discussion, it is limited to the quality of the stones and to methods of improving methods of manufacturing more excellent stones. . . . The first need is therefore a complete shift of focus. What has partly developed as an unplanned by-product must now be seen as clearly within the general responsibility of the educator. Talent and funds formerly restricted to academic purposes in the narrow sense of the term must now be shifted from sheer cultivation of intellectual virtues to education for the *whole* man, for men as knowers and doers and appreciators. . . .

If we in the schools do not live up to our other-than-intellectual responsibility, if we do not reach into moral and emotional fields in a manner that is justifiable from the standpoint of the values of a free society, *someone else will*. For the need exists, and the trend is toward intensification of the pressures that have brought it about. Thus, in a real sense, the survival of a free society may be determined by the flexibility with which we think of the limits of formal education in a changing world.—*Inaugural Address of Harry D. Gideonse as president of Brooklyn College.*

THE MATERIAL BASIS OF EVOLUTION¹

By Dr. SEWALL WRIGHT

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THEORIES of evolution may be classified according to the demands which they make on chance variation. No demands are made by a group of theories under which evolution is a byproduct of individual physiology, whether directed by environmental influences or by the inheritance of individual adaptations or by an innate developmental process (orthogenesis). Theories of this group have had a wide appeal but have been largely discredited by the results of experiment. Under a second group of theories, evolution is a population matter, with varying emphasis on the pressures of recurrent mutation, of selection among individuals and of the effects of inbreeding, cross-breeding and intergroup selection in the hierarchy of partially isolated subdivisions of the species. Finally come the theories under which unique mutations are the crucial events, with subdivision according to whether such mutations are supposed to give rise merely to species, the higher categories arising by a cumulative process, or whether the higher categories as well as the species are supposed to appear abruptly. Dr. Goldschmidt has been the leader in recent years in advocating this last viewpoint on genetic grounds. He has now assembled pertinent data and his deductions from these, in book form,¹ an elaboration of the Silliman Lectures which he delivered at Yale in December, 1939.

The book is not intended to cover the entire field of evolution. It is an "inquiry into the types of hereditary differences which might possibly be used in evolution to produce the great differ-

ences between groups." There are two main parts—"Microevolution" (pp. 8-183) and "Macroevolution" (pp. 184-395)—in accordance with the absolute distinction which Goldschmidt has come to make between evolution within species and the origin of species and higher categories. He reaches the following conclusions with respect to microevolution.

Microevolution within the species proceeds by the accumulation of micromutations and occupation of available ecological niches by the preadapted mutants. Microevolution, especially geographic variation, adapts the species to the different conditions existing in the available range of distribution. Microevolution does not lead beyond the confines of the species and the typical products of microevolution, the geographical races, are not incipient species. There is no such category as incipient species.

The reasons given for concluding that the processes which determine microevolution have nothing to do with macroevolution may be summarized briefly as follows: the observed discontinuity of species and higher categories can not be explained by these processes without postulating an unreasonable amount of extinction of intermediates; these processes are too slow; they are too limited in scope, since it is inconceivable that mutations of protozoan genes could furnish enough material for the evolution of higher animals, even granting duplication; and finally gene mutations are inadequate in kind. "The germ plasm as a whole controls a definite reaction system controlled as a whole by one agency."

As hereditary cytoplasmic differentiation is ruled out as an important factor, the author concludes that only one possibility is left.

¹ *The Material Basis of Evolution*. R. Goldschmidt. Illustrated. v + 436 pp. \$5.00. May, 1940. Yale University Press.

Species and the higher categories originate in single macroevolutionary steps as completely new genetic systems. The genetical process which is involved consists of a repatterning of the chromosomes which results in a new genetic system. The theory of the genes and of the accumulation of micromutants by selection has to be ruled out of this picture. This new genetic system, which may evolve by successive steps of repatterning until a threshold for changed action is reached, produces a change in development which is termed a systemic mutation. Thus selection is at once provided with the material needed for quick macroevolution.

Goldschmidt holds that this theory avoids the insurmountable difficulties which he finds at all points in "neo-Darwinism." As the reviewer is listed among the advocates of neo-Darwinism it may be inferred that he does not find himself in agreement at all points. A detailed critique is not practicable in the scope of this review, but certain general points may be noted.

The antithesis between Goldschmidt's viewpoint and neo-Darwinism is not simply one of preference for systemic chromosomal changes as opposed to micromutations. The neo-Darwinists have not been concerned primarily with the problem which is central in the present book, the types of mutation involved in evolution. Their primary concern is the dynamics of the process, accepting all types of mutation actually observed. As the formal laws of heredity are the same, to a considerable extent, for gene mutations and the simpler chromosomal changes, the same theory applies to both, with minor complications, and has been so applied. Goldschmidt gives no serious discussion of questions of dynamics, and conclusions from statistical genetics are in several cases seriously misinterpreted. Yet the dynamics of the postulated accumulation of subliminal steps in chromosome repatterning and of the establishment of the systemic mutations, once the threshold has been passed, are questions which must be considered, if valid comparisons are to be made with the conclusions reached by neo-Darwinism.

From the latter viewpoint, the species (in sexually reproducing organisms) has a complex reticular structure in time, made up on a fine scale of the conjugating and segregating lineages, and, on coarser scales, of local populations and of subspecies. These groups tend to drift apart under a process that has jointly adaptive and fortuitous aspects (selection in relation to local conditions and effects of inbreeding). They can seldom get very far apart, however, and are continually shifting in character as long as continuity is maintained by cross-breeding. The species as a whole gradually changes its character as a result of intra- and inter-group selection and, under certain conditions, of accidents of sampling. If isolation of any portion of the species becomes sufficiently complete, the continuity of the fabric is broken. The two populations may differ little if any at the time of separation but will drift ever farther apart, each carrying its subspecies with it. The accumulation of genic, chromosomal and cytoplasmic differences tends to lead in the course of ages to intersterility or hybrid sterility, making irrevocable the initial merely geographic or ecologic isolation.

There are certain similarities with results to be expected from Goldschmidt's systemic mutations: subspecies are *not* ordinarily incipient species and there is usually marked discontinuity between species, occurring without any necessary extinction of contemporary intermediates. Under neo-Darwinism, however, these are relative matters, while absolute under Goldschmidt's scheme.

Goldschmidt devotes much space to the "bridgeless gap" between species which is crucial for his theory. To the reviewer, it appears that the data indicate every conceivable intergrade in degrees of morphological and physiological distinction, of chromosomal differentiation and of cross-sterility or hybrid sterility, with the correlation between these criteria far from perfect. Goldschmidt

recognizes the lack of perfect correlation. He holds that "the development of intersterility is therefore to be regarded as the decisive step in the isolation of species." This then is the most essential effect of the systemic mutation. He devotes considerable space to the troublesome cases that have been turning up in increasing numbers in which sharply distinct, non-interbreeding populations living in the same region (and thus apparently good species) have been shown to be connected around a circle by a chain of intergrading types (making them merely subspecies). Goldschmidt, taking the latter horn of the dilemma, decides that the criterion for a good species is demonstrated physiologic intersterility or hybrid sterility, in contrast with failure to interbreed which may be due merely to psychologic causes. Thus he unites into one Rassenkreis two species of deer mice, *Peromyscus leucopus* and *P. gossypinus*, which hybridize rarely if ever in nature, where their ranges overlap, but which have been shown by Dice and Blossom to produce fertile hybrids in the laboratory. He does not, however, refer to the existence of fertile hybrids from crosses between bison and cattle and between pigeons and doves which would relegate accepted genera and families to the level of subspecies by this criterion. Later in the book indeed he recognizes that "good" species (of lepidoptera) may produce fertile hybrids. The question of an absolute difference in kind between the products of microevolution and of macroevolution thus seems to be left in a rather unsatisfactory state. It may be added that he himself to some extent cuts the ground from under the conception of a "bridgeless gap" by suggesting later that genes have no existence except as undefinable regions in the chromosome pattern, that gene mutations are merely highly localized changes in pattern and thus that there is no essential difference in kind between the materials

of microevolution and those of macroevolution. Moreover, the hypothesis that re-patterning may require many steps before a systemic mutation occurs, tacitly reintroduces "incipient species" though not necessarily in the same sense as the recognized subspecies.

With respect to the alleged slowness of neo-Darwinian evolution it may be said that the theoretical rate depends very much on the conditions. Under reasonably stable conditions, with every ecologic niche occupied, theory indicates equilibrium of all gene frequencies to a first order in spite of continual mutation, considerable variability if the population is large, and severe selection. Nevertheless, second-order processes, in a species with a hierarchy of partially isolated subgroups, permit continuous, if usually rather slow, change. There is always the possibility, moreover, that this may lead to an adaptation of a type that is of general significance, perhaps opening up a new way of life. The result of such an adaptation would be a relaxation of selection, a rise in the frequencies of many mutant genes and great increase in variability and in numbers. With ecologic isolation in the various niches now open to the species, and selection pressures now directed differently in each niche, an explosive evolutionary process is to be expected, an adaptive radiation within a new higher category. The same process may occur from a change of conditions. It would seem inevitable if a species reaches an unoccupied region that offers diverse opportunities. Such events must have been relatively common early in geologic time. A relatively recent example seems to be found in the history of the Drepanids of the Hawaiian Islands (an endemic family of birds with 18 highly diversified genera and 40 species, presumably tracing to a pair or flock of stray migrants of an American species) yet Goldschmidt cites this as unimaginable except by an outburst of

systemic mutations of family, generic and specific rank.

It will be well to reiterate that neo-Darwinism is not concerned solely with micromutations. It is quite in accordance with the theory that mutations with conspicuous effects may play an important rôle in the adaptive radiation of populations for which selection is relaxed, provided they do not have deleterious effects on individual physiology or fertility. On the other hand, complex adaptations would be enormously more likely to be reached by a cumulative process, involving trial and error, than by a single step as postulated by Goldschmidt. To the reviewer, the latter's theory seems to make demands on chance that are much too severe, both with respect to the origin of the complex differences between species and their establishment, recalling the postulated abrupt occurrence of intersterility with the parent stock.

The origin of new types by polyploidy is a process in which the individual mutant is the crucial event, which must be recognized by neo-Darwinists as of considerable importance. In these cases, however, there is either little initial change in character (autopolyploidy) or there is a balance of parental character after hybridization (allopolyploidy) favorable to survival. There is a population problem even here, in that the low fertility of triploid hybrids with the parent stock raises severe obstacles to establishment unless vegetative multiplication occurs freely. Goldschmidt himself considers autopolyploidy as falling within the scope of microevolution and does not ascribe primary evolutionary significance to allopolyploidy.

With respect to limitations in the amount of material for evolution provided by gene mutation as compared with chromosome repatterning, it is not clear that the possible combinations of all possible mutations at thousands of loci

furnish less material than the possible permutations resulting from repatterning of normal chromosomes. The evidence at present suggests that the material at each locus (which may be thousands of times as much as that in a large protein molecule) may be capable of mutating through an indefinitely extended, branching series of alleles. Every locus may thus have had an exceedingly complex evolutionary history from protozoan to man.

At the root of the differences between Goldschmidt's viewpoint and that of neo-Darwinism seem to be different conceptions of the physiological relations between germ plasm and organism. The earlier evolutionists, under the influence of a rigid conception of morphological homology, were seriously troubled by the apparent necessity for assuming independent heredities for each part of each replicated structure. An enormous load was lifted when it was recognized that complex differences in form may trace to simple differences in the developmental process and that the same genetic system that determines, through physiological channels, the form of one structure may be expected to give the basis for more or less similar replications wherever the local conditions are sufficiently similar. Goldschmidt has played a leading rôle in bringing home to geneticists the necessity for a physiological interpretation. This general viewpoint is explicitly accepted by all those whom he lists as neo-Darwinists. Goldschmidt, however, seems to hold that the conception of the organism as an integrated reaction system requires a corresponding *spatial* integration of the germ plasm and that essential change in the reaction system can thus come about only by repatterning of the chromosomes. To others, a *temporal* integration is all that is necessary, or even possible, with the chain reaction as the simplified model. Within the organism as a more

or less integrated reaction system, there is a hierarchy of subordinate reaction systems, each with considerable independence, as shown by capacities for self-differentiation. Thus there must be partially isolated reaction systems for each kind of organ and for each kind of cell. It is difficult to see how any spatial pattern in the germ plasm can operate in determining these, but there is no theoretic difficulty with a branching hierarchic system of chain reactions in which genes are brought into effective action whenever presented with the proper substrates, irrespective of their locations in the cells. There is no limit to the number of reaction systems that can be based on the same set of genes, and such systems may obviously evolve more or less independently of each other.

In an introductory chapter, Goldschmidt cites about a score of characters whose evolution he challenges the neo-Darwinist to explain. The actual course of events has usually been so tortuous in cases in which the evidence is reasonably complete that no attempt at reconstruction without direct evidence can be taken very seriously. However, there appear to be no special theoretic difficulties in the cases cited if the neo-Darwinian position is correctly understood. We can only take space for one of these cases but it is typical of several. Goldschmidt holds that alternation of generations could only have arisen by a systemic mutation. Let us consider the case in coelenterates, beginning for sake of argument with a hydra-like polyp, multiplying by budding. Colony formation could arise gradually by the accumulation of micromutations, causing delay in separation of daughter polyps. Differentiation of polyps into nutritive and reproductive zooids involves the same sort of problem as the differentiation of organs within an individual. Alternative reaction systems may become differentiated gradually with expression related to position in the colony. The

reaction system of the reproductive zooid may become modified gradually to provide for increasingly regular separation from the colony and for locomotion, until the medusa type is reached. This, incidentally, offers a new way of life and evolution may continue by gradual suppression of the reaction system of the fixed phase and elaboration of that of the free phase.

So far we have compared Goldschmidt's theory with neo-Darwinism largely on the plausibilities with which they explain evolutionary phenomena. But neo-Darwinism takes its premises from the chromosome theory as actually developed by genetics and cytology. Goldschmidt deduces a different type of chromosomal organization, on the basis of the supposed theoretic necessity of his systemic mutations. No data are given that support the conception of a spatial pattern of the germ plasm, correlated with the reaction system of the organism. Against this is the independence of the chromosomes and the apparent absence of any correlation between location of genes and at least the more conspicuous effects of their mutations. Abundant data indicate that a type gene produces its characteristic effect in translocations whether the translocated piece is small or large, or if large whether the locus is near the right end or the left end or the middle. The effect may be weakened or less stable or otherwise modified, but the type alleles of white, of yellow, of *cubitus interruptus*, etc., of *Drosophila melanogaster* still retain their essential specificities. The simplest description of the genetic data is still obtained by attributing specificity, independent of position, to each gene and merely qualifying this by recognition of occasional second order effects of position. The old question whether adjacent genes are completely separate or are merely specialized regions in a continuum is irrelevant in this connection.

Goldschmidt's contention that char-

acter differences comparable to those between species can not be brought about without repatterning is refuted by the characters of trisomics in *Oenothera*, *Datura*, *Nicotiana*, etc. In these there is no repatterning of any chromosome but merely quantitative increase in all genes of one chromosome, yet the morphological and physiological effects give the appearance of specific difference. On the other hand, a single moderately long inversion should annihilate the pattern of a chromosome as a whole. Yet inversions either have no effect or effects no

greater than single gene mutations. The hypothesis that there is a threshold in repatterning at which the systemic mutation makes its appearance seems to be of a wholly *ad hoc* character.

While the reviewer radically disagrees with the author's central thesis, he wishes to testify to the importance of the book. A great store of well-selected data have been assembled from diverse sources, fairly presented and discussed from viewpoints which must be carefully considered by any one interested in the problem of evolution.

THE BIOLOGICAL BASIS OF VALUE

By NINA BULL

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SINCE the dream of a world made safe for democracy has not come true, and the various unrelated kinds of value that civilized humanity has set such store on are in danger of being swept away, it is high time to consider certain basic values, and their corresponding needs which are forever motivating living creatures, from the lowest to the highest. These basic values all have to do with the conservation of life itself, and can be summed up in a rather general way under the familiar concept of *self-preservation*.

In this concept, however, we need to understand a great deal more than the obvious fact of a strong, persistent compulsion to save one's own skin under the great majority of circumstances. Just as self-preservation in every individual cell within the body takes on a generic form which causes activities concerned with preservation of the organ to which it belongs, and also of the body as a whole, so a single human individual becomes automatically concerned about the preservation of his family, his friends, his group, his country, and even, at times, about the entire human race; so

that any threat to these is registered as *danger*.

The gravest of all dangers to the race is its extinction, and this is avoided by the sexual instinct, which serves the larger end of race or species conservation, although it works through immediate individual needs of pleasure and relief. Goethe has called it nature's trap to lure the individual into the act of reproduction—to keep the race alive. It is essentially a contribution to survival.

Such an elastic concept of self-preservation, which allows for every kind of preservation of the group as well as of the individual, provides a basic principle of motivation, and a biological foundation for the sense of value in itself. And this is true whether the value is positive or negative in character—that is to say, associated with something that produces benefit on the one hand, or something that produces injury on the other. Ideas of "good" grow out of our experience of benefit, and ideas of "evil" out of harm. In the last analysis, all values simmer down to this essential pair, no matter what we call them.

These positive and negative aspects of value can be looked at in various ways. For example, there are two phases of self-preservation in the individual which correspond respectively to the peace and war activities of nations. Peace-time activities, individual as well as national, build for the future—they store supplies, put money in the bank, build up reserves of every kind "against a rainy day." Also, they educate, re-educate, invent, explore, investigate, "create" and play. And special ways of doing all these things determine "cultural" values, in an individual or in a people. Then comes emergency, and all resources and reserves have to be called upon. Perhaps the enemy is actually bearing down on us, and mobilization in the literal sense of the word is demanded. Or, perhaps the educative and investigative process results in enough wisdom to foresee and avert catastrophe, without recourse to "arms."

None of the peace-time values can be correctly estimated, however, unless their contribution to survival is appreciated, and also the special way or ways in which this contribution is made. It is the preparational character that makes them seem important (which is what we mean by *interesting*) even in play, where the individual is living in the present and never thinking of any such connection. The kitten does not know why it is so excited by the falling leaves, and wants to play at catching them. It does not recognize this play as an unconscious kind of education in agility. Most of the play of human beings contains some element of such comparatively painless education, and people struggle with their scores, their form, their rivals, to overcome their own imperfections in this or that direction, and train new faculties, agilities, discriminations, modes of co-operation and the like. The "fun" of play is a device—another one of nature's traps—to lure the individual into prepa-

rational activities for exigencies bound to come. All this is quite apart, of course, from its more immediate recreation value, which contributes to survival in a very different way, counteracting as it does the danger of too much tension.

The two great fundamental values, biologically speaking, are danger and security, and endlessly the instinct of self-preservation concerns itself with both of them—avoiding, coping with, warding off or forestalling some danger on the one hand; and working for, or struggling for, or guarding some security on the other. When these two primitive and fundamental aspects of the instinct of self-preservation are lost sight of *in their relation to each other*, we have the various phenomena of decadence and drifting—where pleasures and skills are continually sought as if ends in themselves, that is to say, without awareness of any biological significance—survival value—attached to them. This vagueness as to the *meaning* of activities is one of the chief causes for the confusion of values that meets us everywhere to-day. It keeps the modern individual uneducated and undeveloped in the all-important region of self-knowledge, through dwelling on secondary reasons for his own behavior because he has no understanding of what is primary in motivation.

The fact that life is threatened from so many different sources, some of them remote in time or space, calling for correspondingly different ways of coping, or escaping, or adjusting, has blinded us increasingly to the presence of a *common understandable denominator* in the motivation of behavior generally. We have become obsessed with our complexity and do not recognize the primitive foundation that underlies it all. And this is not surprising when we realize that play, for instance, besides its educational and recreational values, already mentioned, acquires tremendous values in

prestige (which means survival in the group), and sometimes comes to be a source of livelihood as well.

Once the attention is directed to the matter we can begin to see self-preservation working in many unsuspected places, and often under forms that are opposed to one another. Activities that bring a quick relief from strain have it in common with activities that strain and struggle for future success in this or that direction. And once these facts are realized, it begins to be apparent that there is not an art, a hobby, an ideal, but what is rooted in this biological necessity, under some one or more of its great variety of forms. Spiritual values are endlessly concerned with it, defying death and fostering faith in more harmonious, enduring kinds of living. The virtues are concerned with it, making for social solidarity, and emphasizing protection, guidance and the giving and receiving of help in times of danger. Patriotism is self-preservation working overtime because the group is threatened. . . .

It is not only in the realm of positive activities, however, that self-preservation values are to a very great extent ignored. We are extremely vague about the fundamental nature of most of our negative activities as well, and often fail to see the sense of danger working even in our avoidances and hates. How many people realize, for instance, that their aversion for disorder is rooted in the feeling that there is menace in confusion—so that they either try to escape from it—as from the plague—or grit their teeth and brace themselves for an endurance test, as if disorder were advancing on them physically—like a mob—and had to be resisted? And furthermore, how many people know that their everyday embarrassments are nothing but confusion in evaluation, due to an inability to distinguish clearly the elements of danger in the situation from those of security—or an inability to distinguish different

kinds of danger from one another? The danger of being exploited and the danger of giving offense are very likely to be present simultaneously, and it is only a very accurate appraisal of these elements in the immediate situation that will produce a tactful mode of self-defense. And how many people know that “difficulty,” even in seemingly trivial circumstances, is often sensed as danger and reacted to as such? Or that it is always the blurred but pressing sense of danger in *any* difficult or complicated situation that causes people to escape from it and rush to something pleasanter where they can feel at ease, that is, secure?

The fact is we are accustomed to the thought of danger and self-preservation chiefly in connection with emergency—matters of life and death like accident and fire—and largely fail to recognize the self-same instinct working in its less dramatic forms.

The many unsolved problems of dislike, intensifying into hate, become more understandable when they are taken in connection with an underlying danger-sense, crudely aroused and quite unable to define its object with any degree of precision. Children feel themselves threatened very often, for example, by inadequacy or imposition on the part of adults. But since the older generation represents security *as well as* danger—and with traditional emphasis always on the former—the danger-sense is blurred and gets its only outlet in patterns of dislike, distrust and negative behavior in general.

This lack of precision in defining danger is one of the reasons why dislike and hate, once they become unleashed, tend to destroy much more than just the thing that really menaced to begin with. It is not the reason generally given—but it is the reason which points directly to the only logical control of hate, namely, through the development of a more discriminating sense of what is harmful in

the environment. Even a single step in the direction of such development would be to put our feet on the upward path that leads out of emotional confusion.

The dangers of prolonged emotional confusion are very great, as everybody knows instinctively, and they are now recognized by scientists as working havoc physically as well as mentally. The various "escapes" that serve to divert attention from the difficulty are primarily an effort to avoid this havoc. In short, we must not underestimate the basic value of any escape which succeeds in replacing the misery of a cloudy and persistent sense of danger by a sense of ease and well-being.

Unfortunately, this very genuine therapeutic value is often counterbalanced by at least two forms of consequence which such escape behavior is likely to bring. In the first place, the person who escapes habitually through distraction will never learn to cope with the disturbing situation—as is fairly well recognized in our friends, though not always in ourselves. But the second consequence is much less obvious and at the same time much more far-reaching. It is the inevitable confusion of values that results from habitual escape behavior. Comforts and distractions come to be regularly sought for various secondary reasons, obscuring recognition of the primary relationship between specific forms of security and specific forms of danger.

Escapes that cause oblivion of danger as if by magic are seldom altogether safe after the period of childhood. This is quite aside from the complicating fact that some escapes are "good" in themselves, like hobbies, and some are "bad," like drugs. The fact is, anything at all may come to be used (as an escape) to lull the sense of danger, provided it is sufficiently engrossing. The point that needs especial emphasis is this: whenever the fundamental value of escape *as such*, in providing recreation and relief from too

much strain, is overlooked, the door is closed quite automatically on possibilities of coping with the original disturbance, while another door is opened simultaneously to chaos in matters of evaluation.

The fact that in escaping from one kind of danger we often run directly into others must not be allowed to blind us to the fundamental principles of motivation. Nor must we be confused by the appearances of people choosing what is harmful instead of beneficial to themselves. Whenever this occurs, we may be very certain that the situation does not look that way to them. Even the suicide, commonly cited as a glaring exception to the instinct of self-preservation, is actually escaping from some intolerable nightmare of a situation, that feels to him like an approaching doom. Then it becomes a case where one will choose the lesser of two evils, namely, an easier way to die. If you can give the would-be suicide a ray of hope for living, his re-orientation in the direction of possible security will be accomplished automatically.

Just as no person wants primarily to die, so there is really no one who wants primarily to be selfish or an egotist, but no way occurs to people very often for harmonizing their own self-preservation values with those of other individuals; and hence a great variety of reprehensible activities. Our judgment of our friends and enemies alike is greatly mellowed by introducing these biological considerations. Intolerance is the result of not appreciating how self-preservation works in other people. And it is fortunate that when we work for several ends at once—for future benefits as well as present ones—or for the group as well as for the individual—the greatest satisfaction is experienced.

Apart from this desirable effect, there is also, most fortunately, an unsuspected kind of strength that comes through

recognition by the individual of survival values in his own activities from day to day. It makes for self-respect and the emotional maturity that highly cultured people often envy in primitive personalities in whom self-preservation operates more simply and more consciously. In fact, emotional maturity depends upon such recognition, and no one has to go adventuring in adolescent fashion, searching for danger-thrills to make life interesting, who is already geared into awareness of the omnipresent questions of survival that furnish dignity and meaning to all his daily choices. Danger is always either with us or just around the corner, and the thrill of "living dangerously" comes through alertness to conditions as they actually are.

The concept of self-preservation as the source of all evaluation is radical, in going to the roots of things, but is conservative as well, for it explains and justifies all possible virtues that the human race has striven for. These virtues can be very well summed up under the general heading: *nobility of character*—which most unfortunately is not in fashion nowadays. It represents a high development of the protective instinct as

found in persons who have themselves become emotionally mature.

The recognition of survival value as the basic value has a special implication for present-day democracy, which is beginning to be conscious of certain liabilities that call for serious attention. Our civilization has tricked us somehow, step by step, into an era of dangerously chaotic thinking. This danger was not obvious, however, till we were threatened by totalitarian groups which have acquired the solidarity that comes through the adoption of any common set of values. How to emerge from our confusion without resorting to pre-civilization levels is our immediate concern; how to conserve our liberty of conscience without becoming always more chaotic.

If we believers in democracy propose to go on trusting in the individual sense of values as heretofore, it is clear we must provide some standard of evaluation that all can share—and one that is beyond all controversy, because it is in line with common sense; a standard that allows for interplay between the "selfish" interests and "unselfish" ones, and introduces biological significance into the ancient and indispensable ideas of good and evil.

MYCETOZOA, ANIMAL-PLANT ORGANISMS¹

By LLOYD G. CARR

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IN the realm of "nature in miniature" there are many odd and interesting organisms worthy of special attention. Here may be placed the slime-molds or Mycetozoa, certain inhabitants of galls, unicellular algae, protozoa, and others. Most of these require optical devices for detection, but to the sharp eye the fruiting bodies of the slime-molds become at once visible.

Discovery of the fruiting bodies requires careful examination of rotten leaves or decayed logs. Moss occasionally affords an adequate base. Logs or leaves collected at the foot of a wooded incline, and leaves collected in shaded rock pockets are favorite spots. I have always been successful in locating interesting and odd forms around the sides of shaded limestone sinks. Such sinks are bowl-shaped in outline and present a gradual decline terminating in pools of water. Cliffs with out-jutting projections are usually present on the sides of the sinks. These projections afford excellent pockets in which leaves collect. In the process of decay the leaves hold much moisture and furnish a medium for the growth of bacteria. In these places and under such conditions the slime-molds thrive. Those forms fond of lime will be found particularly in the sinks, for water seeping over limestone carries with it copious quantities of dissolved calcium carbonate which easily becomes available for the slime-molds' incorporation.

Favorite spots for forms requiring little lime are shaded edges of ponds or moist ravines and hollows. Here, in leaf or stick-heaps, on rotten stumps or

logs, a varied display of forms usually awaits the earnest collector. Certain forms will be found only on logs; others on leaves, whereas a few slime-molds confine themselves to more specific habitats. For instance, there are two forms that occur regularly each season on dead chestnut burrs and rarely appear elsewhere. *Arcyria globosa*, the netted slime-mold, and *Craterium concinnum*, the goblet-shaped slime-mold, select this special home.

The "fairy ring" slime-mold or *Physarum cinereum* is frequently found on lawns and has been referred to as the "lawn marvel." To see its fairy ring formation enclosing diameters of from six to eleven feet on a green background is an impressive sight. Another species that frequently turns up is the "flowers of tan" or *Fuligo septica*. It has a fondness for decayed sawdust piles where it often spreads in compact masses covering several square feet. It is readily detected by the yellow crust that envelops the small "puff-balls."

Best results are obtained in "myceto-zoanizing" during the summer and fall months a few days after a rain, when almost any rotten log will furnish myriads of fruiting bodies in little fairy-like colonies.

Considering the slime-molds, which the zoologist calls Mycetozoa (fungus-animal) and the botanist Myxomycetes (slime-fungus), we are confronted with a group possessing a unique life history, structure and a variety of unusual forms. As the names applied indicate, these organisms hold affinity with both plants and animals. From the resemblance of the fruiting bodies to small puff-balls the early workers naturally

¹ My appreciation goes to Dr. Ivey F. Lewis for interest in this manuscript.

included them with the fungi, but when their life history was more completely understood through the efforts of Fries, Wallroth, de Bary, Cienkowski and Rostafinski, early pioneers in biological thought, there was doubt as to where they belong.

The change of this organism from an animal to a plant status may be noted by bringing home pieces of wood or leaves carrying the seething plasmodium, which has resulted from the fusion of germinated spores that finally produce the slimy mass of protoplasm. In almost any tract of woodland this gelatinous growth may be located. It appears rather conspicuously in its yellow, orange or white coats, trailing over leaves, bark or fern stipes, where it sometimes forms a lacy pattern. I have seen it climbing old tree trunks to prey on the rich supply of bacteria afforded by the decaying wood. By placing the wood or leaf substratum in shallow dishes which have been lined with moistened paper, we may see the protoplasm forming hundreds of little "puff-balls." First the plasmodium will become thicker and less fluid-like; then the globular bodies that finally terminate as mature sporangia will follow. Similar results may be secured by germinating the dried plasmodium or sclerotia on moist paper, with intervals of feeding on oats until fruiting ensues.

Careful examination of the structure of these bodies reveals a unique complexity and discloses to the curious observer fascinating aspects for investigation. On crushing a "puff-ball" on a slide in a drop of water, with subsequent microscopic examination, there come to view many spores variously scattered throughout the field of vision. Often these are attached to a thread-like net or capillitium that is characteristic of most of these organisms. High magnification shows delicate sculpturings on the spores. The mosaic may be a reticu-

late net formed by the union of numerous bands or rings, some of which are pitted. A few forms have spores with warts generally distributed over the surfaces, whereas a number have bulb-resembling protuberances.

The fruiting bodies of the netted arcyrrias and hemitrichias, the goblet-shaped crateriums and the lime-knotted physarums are beautiful in color, shape and structure. They may be iridescent, approaching the hues of the rainbow, blue or green, orange, red, rose, yellow or nut brown. Their "puffballs" develop as pretzel or snake-like bodies or in groups where individual sporangia are indistinguishable, but more frequently display distinct and separate units.

External examination of the "puffballs" presents walls that function in holding together the mass of netted threads. Occasionally there are two walls evident and sometimes three. These may be closely compressed or slightly raised over the spores. In the physarums, badhamias, didymiums, fuligos, etc., the walls are composed of crystalline lime granules. This condition results when the plasmodium at the time of fruiting discharges a copious quantity of lime in aqueous solution. Subsequent evaporation of the limy fluid segregates the granules into compact walls or layers. These may assume a stellate or spherical shape. The physarums, crateriums and fuligos possess rounded granules in their structures, while the didymiums have the stellate type.

The action involved in wall-and-"puffball" formation and granular segregation is interesting. Robert Hagelstein has described the curious phenomenon in the stellate form, *Didymium crustaceum*.²

The outer crust of pure lime crystals is here re-

² Robert Hagelstein, *Mycologia*, 30: 3, May-June, 1938.

garded as distinct and forming separately from the sporangium proper. It is very fragile, crumbling and disappearing with the slightest disturbance. When perfectly developed it is not attached to the sporangium but covers it like an inverted jar. It seems to form by the rapid evaporation and crystallization of the saturated medium containing lime in solution which is discharged by the plasmodium when it divides to form sporangia. The outer side would be smooth from surface tension. As sporangial formation proceeds within, and with consequent contraction, there would be a layer of the liquid between the outer formed crust and the forming sporangium. By evaporation, further crystalline deposits of lime would be made wherever the liquid touched, principally on the forming capillitium and spores; on the stalk, or from it to the outer crust along the habitat base; or as connecting masses between the sporangium and outer crust. These deposits may be observed in many sporangia. The confined liquid also plays an important part in the shaping of the irregular sporangia, conforming them to its pressure or the shape of the outer crust.

Dehiscence of the sporangial wall deserves special note from the artistic patterns which are formed. Often the wall falls backward in a petaloid fashion resembling the petals of a miniature water lily, as in *Diderma Treyelyani*. The goblet-shaped crateriums possess well-defined lids which open on the slightest provocation. Often while collecting we will find a number of goblets with their "caps off" and contents blown far afield.

Upon opening, the "puffballs" disclose their beautiful fluff of threads or capillitia among which the spores are scattered. These conform to a special system that may be a meshed net assuming the appearance of a window screen, or perhaps a mass of free threads without any connections to the walls may be present. In some forms the threads are assembled around a main stem, as in *Stemonitis* and *Comatrichia*. The threads in most of the forms usually show unique sculpturing.

In examining the threads of *Arcyria* and *Hemitrichia* another fascinating aspect of the slime-mold's structure is brought to light. We note that the threads of *Arcyria* are decorated with numerous cogs or spines, while *Hemitrichia* turns toward the spiraled type. The spirals are distinct and may easily be counted.

In *Trichia* we meet a capillitium composed solely of free threads haphazardly arranged in a mass. These threads when at play exercise a quick jerky, elater-like action that assists in dispersing the spores. These elaters appear as though they are wound with fine strands of yellow silk.

In the physarums, crateriums and fuligos capillitia of knots filled with rounded granules are evident. The lime-knots are colored in tints of red, orange, yellow, brown and white, being disposed in fusiform, angular or rounded groups, which are connected by hyaline threads. The picture of knots as a whole forms a fantastic and odd pattern pleasing to the artistic eye. In the badhamias there exists an irregular papery mass of lime built as jagged partitions throughout the fruiting bodies.

In our brief survey we have encountered a complex organism carrying on its existence in much the same way as higher organisms, revealing the features that associate it with life, and maintaining its status in its own sphere of unity on as high a scale of perfection as the more advanced animal and plant groups. The uniqueness of the group in representing a link between animal and plant life, through its transformation of a streaming protoplasm into hundreds of tiny "puffballs," graphically pictures the close relation of animal to plant and their connecting cord.

BOOKS ON SCIENCE FOR LAYMEN

WHEN THE EARTH SHAKES:

The author of "Our Trembling Earth" is the distinguished head of the Fordham seismological observatory and chairman of an active committee on amateur seismology. The book fills a gap in the limited list of publications on earthquakes by presenting an account of the complete field of seismology in a popular and humanistic style. The layman whose knowledge of earthquakes has been limited heretofore to newspaper accounts will find much satisfaction in the present book.

The author, after summarily discussing the nature of earthquakes, explains how they are located from instrumental records. He devotes interesting pages to the geological interpretation of seismograms, and shows, with the help of reproductions of actual seismic records, how the latest knowledge of the internal constitution of the earth has been acquired. In this regard, he proposes some original theories of his own. He emphasizes the remarkable and exemplary cooperation between the observatories of individual stations, the Coast and Geodetic Survey and the Jesuit Seismological Association. The inevitable question: "Of what value is the instrumental study of earthquakes?" is answered by the author in three chapters devoted to the aims, both practical and academic, of seismology. The book closes with a discussion on amateur seismology, including instructions on how to build instruments capable of recording distant quakes.

Throughout the book, human interest is heightened by off-the-record stories of incidents, both happy and tragic, which break the humdrum routine of the seismologist. "Our Trembling Earth,"

1. *Our Trembling Earth*. Joseph Lynch, S.J. Illustrated. 302 pp. \$5.00. 1940. Dodd, Mead and Company.

written in a sparkling style by a scientist of wide experience, is an up-to-the-minute and remarkably complete picture of seismology.

WALTER J. REEVE, S.J.

PRACTICAL AND THEORETICAL CULTURE STUDY:

At last, a full exposition of the culture historical method of ethnology is available in English. Recognizing that Graebner's earlier presentation of the methods of the Graebner-Schmidt-Koppers or Vienna historical school given in "Methode der Ethnologie" (1911) was difficult even for German-speaking people to understand and evidently hoping that a comprehensive statement of its position that included answers to many criticisms would disseminate a wider comprehension and therefore acceptance of its views, Father Schmidt wrote "Handbuch der Methode der Kulturhistorischen Ethnologie" (Münster, 1937), of which the present volume is a translation by S. A. Sieber.

It is perhaps far more important in methodological considerations to recognize that use of a certain method by no means guarantees consistent results than it is to attempt criticism of that method. As a matter of fact, the quarrels between the various schools of anthropology have generally turned less upon their abstract methodological declarations than upon what they think is worth doing and what they actually do. Stripped of actual application and reduced to abstractions, contending views are usually seen not to be irreconcilable but to contribute goals to some common mill. It is somewhat astonishing that a school that has produced results that are so generally rejected in America as those of the Vienna

1. *The Culture Historical Method of Ethnology*. Wilhelm Schmidt. trans. S. A. Sieber. 302 pp. \$5.00. 1940. Fortress.

school should have a methodology which is almost entirely acceptable. And yet there is scarcely an assumption, hardly a point of logic in the present volume with which one will seriously disagree. Father Schmidt has expounded with incomparable, almost tedious, thoroughness every rule and subrule for reconstructing culture history. He has squarely met previous criticisms of his methods and shown that everything from archeology to functionalism and even a psychological approach is theoretically compatible with his point of view and can contribute to history. The details set forth for appraising and utilizing source materials (Chapter II) are not likely to cause disagreement. Even the means for establishing culture relations (Chapter III), kulturkreise (translated culture circles) and culture strata (Chapter IV), internal culture development (Chapter V) and culture causality (Chapter VI) contain very little that is truly controversial. No one will seriously doubt that two or more culture complexes made up of elements which are sufficiently similar (qualitative criterion) and sufficiently numerous (quantitative criterion)—“sufficiently,” of course, is subject to individual interpretation—are genetically related, especially when due consideration has been given to the geographical situation of the complexes, to the “organic unity” of the cultures, to the possibility of independent invention and to other pertinent factors—all of which Father Schmidt reduces to a long series of rules. One could agree, in fact, with every word of Father Schmidt’s presentation of method and yet remain no less skeptical of the historical reconstructions that he has so abundantly made and published in many other works. How is it possible that scientists can agree on abstract methodology and yet arrive at substantially different conclusions?

The answer is that no amount of

methodologizing rules out a crucial element of subjective judgment—a judgment that evidently springs as much from the scientist’s milieu as from his attempts to use sheer reason. As Father Schmidt directs certain criticisms and reproaches particularly at Americans, eleven of whom he singles out for comment, it is of some interest to inquire what differences exist between the American and Vienna schools.

First and foremost, Americans have been absorpt in field work in the Indian groups at their own backdoor, whereas the Vienna scientists have turned to libraries and museums for research materials. The pressure of work has not only left Americans little time for methodologizing but has minimized its importance. An American research worker obtaining materials direct from the native group or personally acquainted with those who are doing so has no more interest in a formal and comprehensive set of principles concerning the discovery, collection, meaning and criticism of sources (Chapter II, pp. 83–135, written by Koppers) than a person who has to cross the street many times daily has for rules governing each step. It is understandable that these rules should have been developed where research was mainly in the library.

But the American environment has also produced a point of view and a procedure for reconstructing history which, although infrequently stated as an abstract proposition, is fairly consistently implied in at least the better products of American research. In contrast to the kulturkreis workers, who reconstruct history on a world scale, Americans have devoted themselves to restricted tribes or areas. This is not done because, as Father Schmidt seems to contend, they have a predisposition to regard the culture area as the ultimate historical unit—to which he opposes the kulturkreis—but because of a conviction that the most reliable historical materials come from a

detailed study of the continuum of development of each local, functioning culture unit. Furthermore, Americans tend, admittedly or not, to adopt a somewhat scientific attitude, whereas Father Schmidt is frankly and thoroughly historical and nonscientific. (Even the chapter on "culture causality" regards causes as the specific antecedents of particular events, not as causal factors which, from a scientific point of view, have repeatedly produced a similar effect.) And it is significant that American historical interpretations often resemble Father Schmidt's in proportion as the authors deliberately disavow a scientific approach. The crucial difference, then, between the American and Vienna schools is that the former, making detailed studies of culture process in restricted areas, see like causes producing like effects—for example, agriculture, house types, clothing, social institutions—perhaps once in each hemisphere, perhaps many times in different localities. Thus, without disputing Father Schmidt's abstract rules, they doubt that cultural similarities in different parts of the world are usually explainable by genetic relationship and are reducible to *kulturkreise* and sequences.

It is evident, therefore, that the essential differences in interpreting ethnological data are no more subsumed in the formal rules presented in this volume than they are in most American theories that are presented *in vacuo*, but that they are nevertheless real and are clearly implicit in much actual research. The implication would seem to be that it is incumbent on Americans to make their own methodology more explicit but that for the present, at least, methodological declarations will be far clearer and more convincing if they are embedded in pieces of substantial research. It is almost an obligation, however, that, in clarifying their own methodology, Americans give Father Schmidt's volume the most care-

ful consideration. It contains so much solid thought and painstaking analysis that, as Kluckhohn remarks in his Preface, "To follow the argument (often of intricately reasoned structure) surely means an enrichment of one's own perspective on techniques, methods, theory, and methodology," and, we might add, on himself.

JULIAN H. STEWARD

AN ELEMENTARY BOOK ON CONSERVATION¹

THIS is a school text-book on conservation, superbly planned and organized, well made and illustrated. It is so written as to sustain interest throughout. Two chapters are devoted to the physical and historical background of American wastefulness which has made conservation such a live issue. The remaining seven chapters are concerned, in order, with soil, water, forest, grassland, wildlife, minerals and human resources. The balance and completeness of this treatment are admirable.

The animating idea of the book is twofold. First, conservation is an immediate and critical problem. Second, every one can do something about it. It is taught here distinctly as an activity. The principle of sustained yield is emphasized as the very heart of the conservation enterprise.

In view of the likelihood of widespread use, the reviewer hopes that publisher and authors will take occasion to revise the book soon, eliminating a number of scattered but significant blemishes. These appear particularly in the important early chapters. For example, on page 4 occurs the statement, "Natural resources by themselves exist in a friendly neighborhood of help-one-another." The idea of good-will belongs in this book, but certainly not in that context. In fact, on page 6 the authors find

¹ *This is Our Land*. E. G. Cheyney and T. Schantz-Hansen. Illustrated. 337 pp. \$3.00. Webb Publishing Company.

it necessary to say, "Even when left to themselves, natural resources have frequent squabbles." This is all dangerous stuff to put into the elementary schools—particularly in a country which is suffering, as is ours, from wide-spread scientific illiteracy.

Again, in discussing the very basis of the whole problem, the balance of nature, there is not the slightest hint of the rôle played by solar energy. The soil is credited with being the source of food, by inference on page 51 even supplying carbon. Nor is the vital fact that soil represents an organized system sufficiently developed.

Elsewhere the impression is given that eastern China has been converted into desert in the past two centuries. Kentucky, West Virginia and Tennessee are catalogued as part of a region free from mountains. The ocean is likened to the Sahara desert in that it has numerous oases *below the surface*; the location and importance of plankton is ignored. The author uses the debatable distinction between renewable and unrenovable resources. Renewability depends less upon the resources than upon ourselves.

The making of text-books is serious business, in which the best of authors needs expert help from his publisher. Authors, publisher and public alike will benefit by an adequately revised edition of this excellent book.

It should be noted that Jay N. Darling, patron saint of conservation, has contributed a pungent foreword, as well as the use of his classic cartoon, "Outline of History."

PAUL B. SEARS

THE SCIENCE OF PERSONALITY FUNCTION

THIS text is adapted to a didactic study designed to emphasize to physicians the value of practical examination, under-

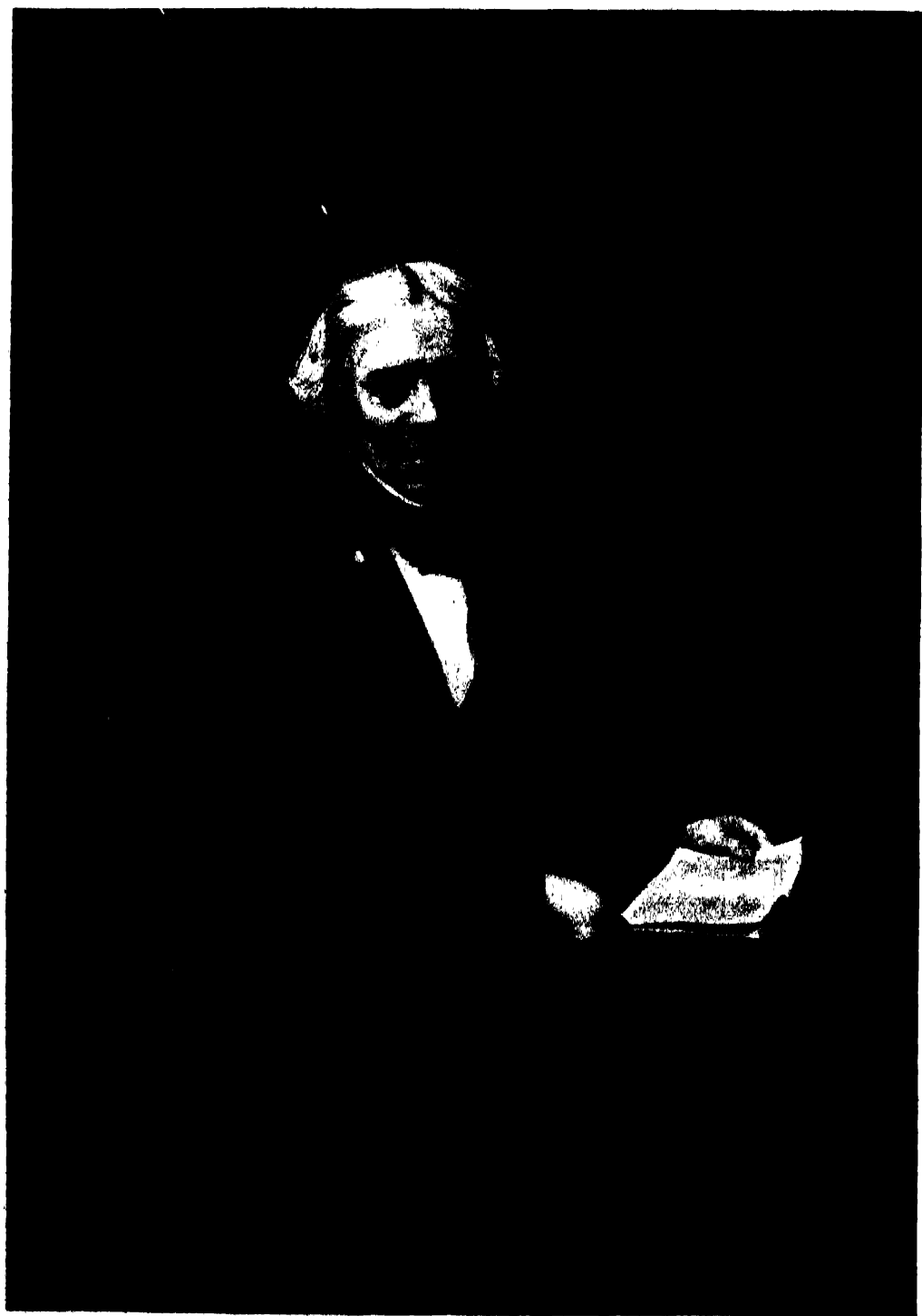
A Handbook of Elementary Psychobiology and Psychiatry. Edward G. Billings. xix + 271 pp. \$2.00. 1939. The Macmillan Company.

standing and treatment of psychological problems in general medical practice. In a study and treatment of the patient's complaints referred to organs the person as a whole has been neglected; the book, like many volumes in current psychiatric literature, utilizes the holistic and biologic approach to the disorders of personality functioning in general medicine.

Psychobiology is defined as the physiology of the individual, or the science of personality function. Life, with its properties of organization with growth, metabolism and reproduction, is studied as an "experiment of nature"; mentation has no structural representation other than the whole person and therefore can only be viewed as it is manifested in action or behavior with meaning. Overt and implicit functions of man can not be separated into that of the mind or that of the body but are integrated in the total personality organization.

Psychobiology has to do with the study of the mentally integrated functions of human beings, both normal and abnormal ones, while psychiatry is more pointed, dealing with psychopathological reactions which lead to complaint problems. The psychobiological school of thought of Adolph Meyer has introduced into psychiatry a new vocabulary: *ergasia* (personality at work), *ergasiology* (study of the functioning total organism), and *ergasiatrics* (study of abnormal personality reactions), which perhaps is timely. Improved methods of communication by language has been stimulating in the relatively new medical speciality of psychiatry. "Elementary psychobiology" is not for the usual elementary student. Dr. Billings's general principles of psychotherapy are conservative and based upon the broad definition of treatment of Webster's International Dictionary, *viz.*, "the management and care of a patient or the combating of his disorder."

R. H. GUTHRIE



MICHAEL FARADAY
ENGRAVED BY D. J. POUND FROM A PHOTOGRAPH BY MAYALL.

THE PROGRESS OF SCIENCE

MICHAEL FARADAY, 1791-1867

MICHAEL FARADAY, the son of a blacksmith, was born 150 years ago in London, England. In his youth he was apprenticed as a bookbinder, and in his early manhood he became a chemist. Among his contributions as a chemist, he liquefied several gases, he studied several alloys of steel and he produced several new kinds of optical glass. His great fame rests, however, almost entirely on his discoveries of the relations between electricity and magnetism.

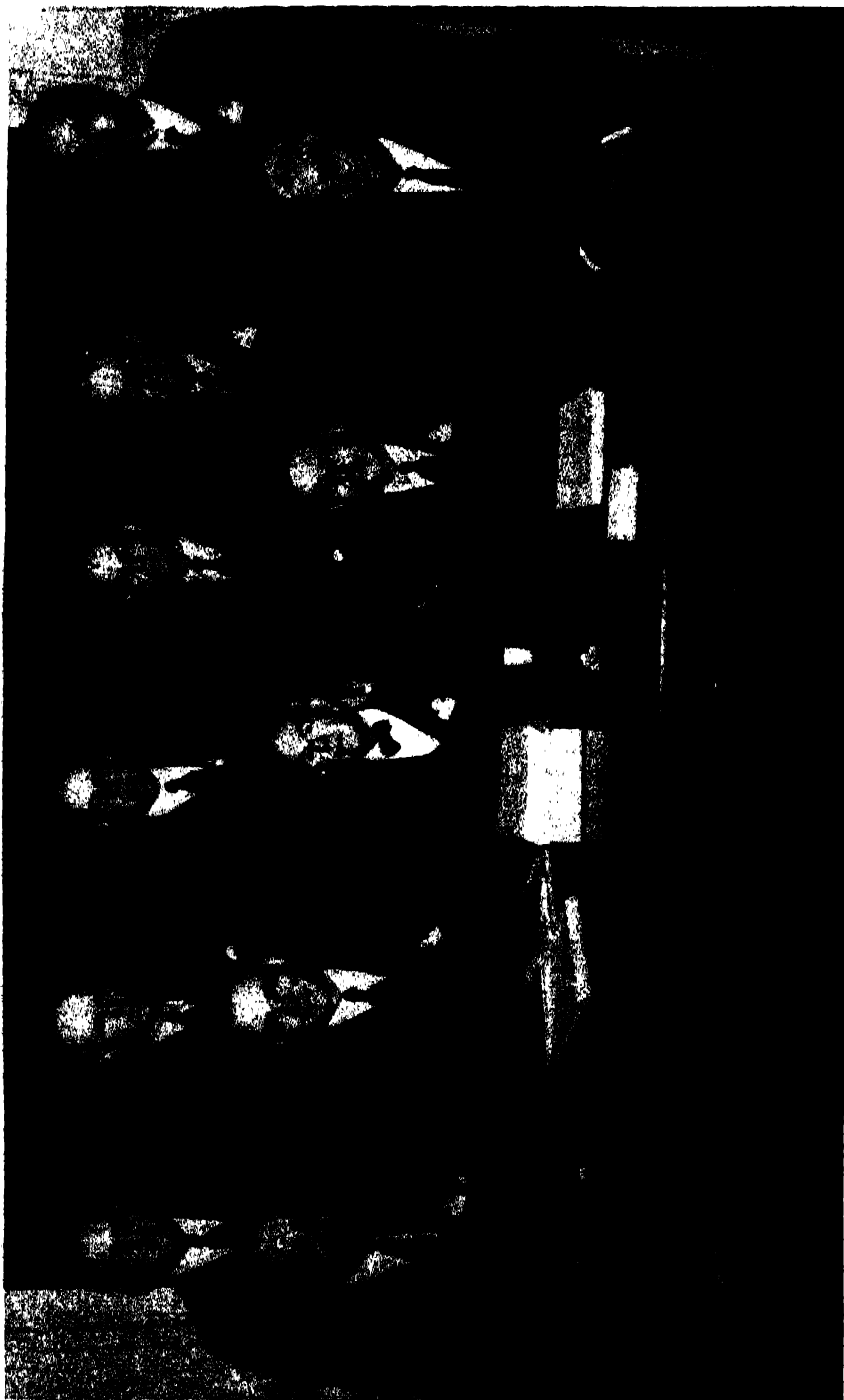
It is extremely difficult now for us to understand the state of knowledge of electricity in Faraday's day. It was known that it is not conducted by glass but that it is conducted by copper, a substance several times as dense. It was long before there were any plausible explanations of how electricity is conducted through certain solid bodies. A more mystifying property of electricity is that it is related to magnetism. By 1820 Oersted was making approaches to the subject. In 1821, one hundred and twenty years ago, Faraday published his first paper on the relations between electricity and magnetism—that electric currents will produce magnetic effects in their vicinity and that magnets moving near conductors will produce electric currents in wires with which they have no physical connection. Apparently these phenomena flatly contradict the theory that physical phenomena necessarily depend upon successions of contacts of physical objects. At any rate, the observed phenomena were astonishing. Faraday not only discovered them but worked out the laws that describe their quantitative relations.

In 1831 Faraday published a paper in which he described how an electric current in one wire could generate an electric current in a suitably placed but wholly independent second wire and

worked out by experiments the laws relating to currents in the two wires. These results lie at the basis of the construction and operation of electrical transformers, which are as essential for the present electric industry as are power plants and generating stations. Faraday was not alone, however, in his attacks on electrical problems. Joseph Henry, in this country, was paralleling his work in many respects. It detracts nothing from the fame of either that the other was simultaneously exploring the same mysterious and fruitful unknown regions.

How fruitful the electromagnetic theory has been! In conformity with it electricity is generated in power plants by rotating pieces of iron wrapped in wires in the neighborhood of other pieces of iron wrapped in wires. This mysterious energy travels invisibly and silently along wires, a hundred thousand horsepower along little wires suspended from towers. A bird can sit on them wholly undisturbed by the torrents of energy they carry. If the distance is far, the energy is transformed to higher voltage by equally astonishing means. Two sets of coils of wire are placed near each other, but they are not connected. The electricity flows into one coil at a certain voltage; it flows out the other at a different voltage. At some distant point it is transformed again down to a voltage that is safe to use. The distribution of industries and populations and a thousand other aspects of modern life depend upon the properties of electrical energy mentioned here.

Consider for a moment wireless communication which depends upon the same principles. Oscillating electric currents in the sending station produce corresponding electromagnetic changes in



THE EXECUTIVE COMMITTEE OF THE ASSOCIATION AT THE PHILADELPHIA MEETINGS

Seating: ROGER ADAMS, ROY E. CLAUSEN, OTIS W. CALDWELL, ESMOND E. LONG, HENRY B. WARD, GEORGE D. BIRKHOFF. *Sitting:* EDWIN G. CONKLIN, F. E. MOULTON, J. MCKEEN CATTELL, ALBERT F. BLAKESLEE AND BURTON E. LIVINGSTON

space. They move with the speed of light. Are they transmitted by or through the ether? Those are words that tend to hide our ignorance. They are reflected from the Heaviside layer, which is so high above the surface of the earth that we ordinarily would call it a vacuum. Perhaps they are reflected again, this time by the earth's surface. After repeated reflections they reach some distant wires in which they generate extremely feeble electric currents. After amplifications and transformations they may be turned into a voice from Europe or South America. These

are the consequences of the electromagnetic principles Faraday discovered only about a century ago. Nearly all the applications have been developed during the past fifty years, and many of them within twenty years.

Just now we are listening with fear to the tread of Hitler's legions. After their very echoes have died away and been forgotten Faraday's contributions to the electromagnetic theory will be held in grateful remembrance and the anniversary of his birth will be noted throughout the earth, as it is now.

F. R. M.

NEW HAMPSHIRE MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MEMBERS of the American Association for the Advancement of Science and of its affiliated societies for several months looked forward with happy anticipations to the meeting they were to hold at Durham, New Hampshire, from June 23 to June 28. All their anticipations were realized. They found that the University of New Hampshire is delightfully located in a gently rolling country between the lakes and the sea; that its buildings are commodious and well appointed; and that excellent arrangements had been made to provide for the comfort of all who attended the meeting. For a few days the scientists who gathered at Durham lived peaceful and harmonious lives, almost unmindful of the tragic events that were disturbing the world.

There were only two general sessions, the first under the sponsorship of Pi Gamma Mu, the National Social Science Honor Society, at which Dr. F. R. Moulton spoke on "Our Social Order," and the second a distinguished address on "The Basis for Faith in Democracy," by Dr. Max Schoen, which was delivered under the auspices of the New Hampshire chapter of the Honor Society of Phi Kappa Phi. Pi Gamma Mu and Phi Kappa Phi sponsor addresses at summer

meetings of the association, and the Society of the Sigma Xi and the United Chapters of the Phi Beta Kappa corresponding addresses at its winter meetings. These broad surveys of special fields of science and society emphasize the fact that in spite of their subdivisions and differences the natural and social sciences have the common aim of advancing human welfare.

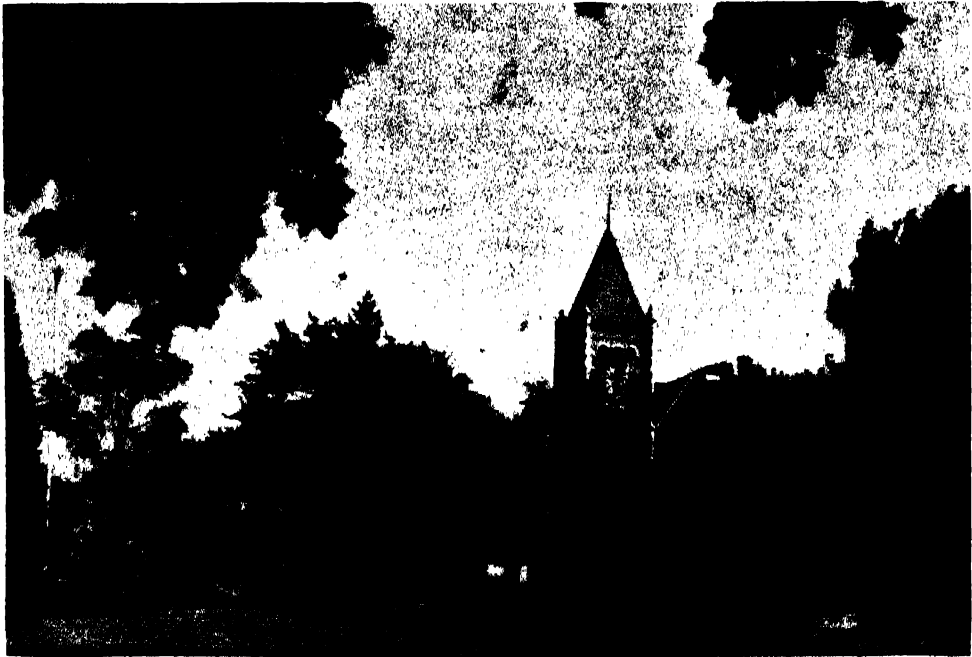
After the close of the first general session, the University of New Hampshire tendered a reception to members of the association and of its affiliated societies and to their guests. On the fourth evening the university provided a concert in the Field House, at which a chorus of three hundred and fifty voices sang Haydn's *The Creation*. The accompaniment was by the New Hampshire Youth Orchestra of eighty pieces. Each afternoon an exhibition of motion pictures on a wide variety of scientific subjects was open to the public.

During the meeting more than two hundred formal papers and addresses were presented. They included contributions to mathematics and meteorology, discussions in the fields of geology and geography, a symposium on the chemical control of insects, a large number of

papers on botanical subjects, a program on psychology, a series of papers on population questions in New England, eighteen papers on medical subjects, a group of papers by the American Psychiatric Association on civilian morale and a large number of papers on various problems of agronomy, forestry and horticulture. These numerous formal sessions were, however, only a part of the program of the meeting. The meteorologists joined in an excursion to the summit of Mount Washington, the highest mountain in New England. The geographers and geologists conducted a one-day field excursion for the examination of geographic and geologic features of the Durham area, and a three-day excursion through the White Mountains, including the ascent of Mount Washington, for the purpose of examining the evidence in support of the recent interpretations of some of the most complex mountain formations in the United States. Of all the

scientists, the botanists took the most extensive excursions. They not only visited the White Mountains and Mount Washington, but also most of Maine. The phytopathologists visited plant research laboratories and experiment stations in various parts of Connecticut. The Torrey Botanical Club, the Ecological Society of America and other societies joined in excursions to Mount Monadnock, Spruce Hole, Cedar Swamp and other interesting localities. The agronomists, the foresters and the horticulturists participated in many field trips to points of special interest to themselves.

As interesting and enjoyable as the excursions and field trips were, they were not simply pleasant outings. On the contrary, they were taken with serious purposes and undoubtedly contributed as much to the advancement of science as would an equal number of days devoted to listening to reports on scientific investigations. It is a characteristic of



THOMPSON HALL, ADMINISTRATION BUILDING OF THE UNIVERSITY OF
NEW HAMPSHIRE



HAMILTON SMITH LIBRARY OF THE UNIVERSITY OF NEW HAMPSHIRE

science that it generally combines work and pleasure, and often the happiest hours of a scientist are his most strenuous.

In the case of the section on the social and economic sciences the program consisted entirely of sessions for the presentation of papers. The general themes of the six sessions of this group were the origins of the peoples of New England and their social and political problems. Too often it is carelessly assumed that the present people of New England are the descendants of the Pilgrims and other

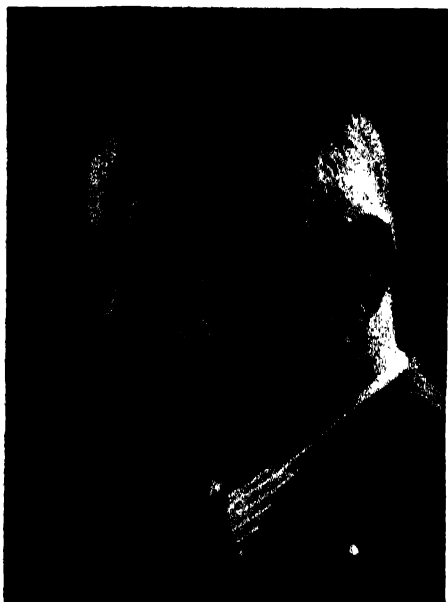
early settlers. As a matter of fact, later immigrations of Irish, French Canadians, Italians and many other peoples have entirely changed the picture. The many interesting consequences of these almost unparalleled transformations of populations in one of the oldest sections of our country were discussed in a series of very distinguished papers. Their publication would be an important contribution to an understanding of present New England.

F. R. MOULTON,
Permanent Secretary

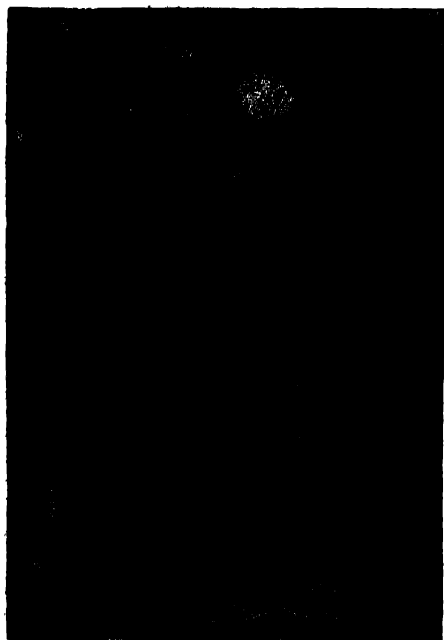
PRESENTATION OF THE MEYER MEDAL TO DR. EDMUNDO NAVARRO DE ANDRADE

IN recognition of his outstanding accomplishments in the introduction and utilization of Eucalyptus in Brazil, the council of the American Genetic Association has awarded Dr. Edmundo Navarro de Andrade the Meyer Medal. It was presented at the U. S. Plant Introduction Station at Glenn Dale, Mary-

land, on the afternoon of June 2. Dr. Navarro is the seventeenth plant explorer to be awarded the Meyer Medal, which was established in 1919, in memory of Frank N. Meyer, who for many years combed far corners of China to find new plants for American farms and gardens.



DR. EDMUNDO NAVARRO DE ANDRADE

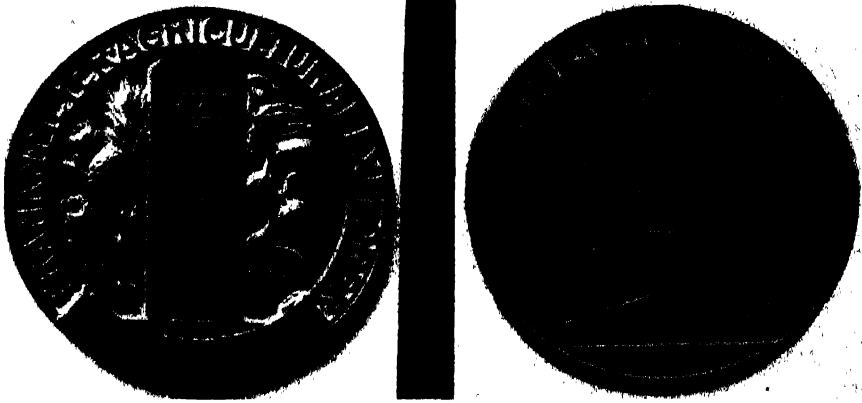


A EUCALYPTUS FOREST
IN SÃO CARLOS. THE TREES ON THE LEFT SIDE
OF THE ROAD ARE ELEVEN YEARS OLD; THOSE ON
THE RIGHT ARE TWO YEARS OLDER.

In making the presentation in behalf of the council of the American Genetic Association, Mr. B. Y. Morrison, head of the plant introduction service of the U. S. Department of Agriculture, said that fortunately not only the plant immigrants travel, but the people who are concerned with their wanderings as well. Thus the small group of plant explorers and experimenters with new plants all over the world represent a very delightful and in such a time of stress, a very important bond between the nations. Furthermore in so uncertain a world, this brotherhood of plantmen have as their common interest something real and relatively solid and unchanging—the living plants themselves, rather than symbolisms and abstractions. In building bridges of closer relationship between the Americas such solid bonds are to-day most valuable.

Following the award Dr. Navarro gave an evening lecture at the auditorium of the Cosmos Club in Washington. Here he told in some detail his experiments and experiences with Eucalyptus in Brazil. He graduated from the University of Coimbra in Portugal in 1903, and later that year was appointed by Antonio Prado, president of the Paulista Railroad, to find ways to meet the fuel needs of the railroad. Since wood is used for fuel on most of the Brazilian railroads, Prado saw that the improvident use of the forests for fuel was eventually going to be disastrous unless growth and utilization could be balanced. To solve this problem he established a forestry section and put Navarro in charge of it.

To determine which species of trees grew most rapidly in São Paulo, Navarro established extensive tree plantings with over a hundred species of the most promising native Brazilian trees, and with as many introduced trees as he could lay his hands on. Among these were some Eucalyptus Navarro had brought back with him from Portugal;



THE MEYER MEDAL OF THE AMERICAN GENETIC ASSOCIATION

Left: ON THE LEFT IS A WHITE-BARKED PINE CONE AND ON THE RIGHT A FRUITING BRANCH OF THE CHINESE JUJUBE. THE CHINESE INSCRIPTION IS "IN THE GLORIOUS LUXURIANCE OF THE HUNDRED PLANTS HE TAKES DELIGHT." *Right:* A SCENE DEPICTING QUEEN HATSHEPSUT'S EXPEDITION TO THE LAND OF PUNT.

others were obtained from California and South Africa, and later many more from Australia. Of all the trees tested the best of the eucalypts far outgrew all competitors.

In order to get the best adapted species Navarro visited the United States in 1910, and three years later the homeland of the genus, Australia. There he received the cordial help of Professor J. H. Maiden, the acknowledged world authority on this genus. He was able under Professor Maiden's guidance to round out his already wide knowledge of the genus. As a result of these journeys Navarro established at the Rio Claro Station in São Paulo an arboretum containing 123 species of Eucalyptus, the most extensive collection of trees of this genus to be found anywhere in the world.

Through mass plantings under varied conditions Navarro chose about two dozen species which were best adapted for forest planting in Brazil. When he undertook to gain support for this project to balance Brazil's firewood budget he was met with almost fanatical opposition, an intense botanical chauvinism which denied that any imported tree

could possibly be as good for any purpose as some of the numerous native trees of Brazil. Appeals to experiments on a large scale proving that the yield per acre-year of Eucalyptus wood far exceeded that of other trees only shifted the attack to other points—the wood would not burn, the smoke would injure or asphyxiate the locomotive crews, etc. As for using Eucalyptus for any other purpose, preposterous! The campaign of demonstration and education to prove the falsity of these objections took longer than the experiments to determine the best species in the first place. This is all the more curious because coffee, the premier money-crop of Brazil, is itself a plant immigrant.

In recent years Dr. Navarro's long fight for the acceptance of Eucalyptus has silenced effective opposition. The Paulista Railroad, which sponsored the first experiments, has led in putting these experiments to work. To-day this railroad has seventeen huge Eucalyptus forests totalling 21 million trees, with projected additional plantings at the rate of two million trees a year until a total of 35 million is reached. This will meet the fuel needs of the 1,800 miles of



EUCALYPTUS IN SAO CARLOS—SEVENTEEN MONTHS OLD

wood-burning line maintained by the Paulista Company. Other Brazilian railroads and other large users of firewood and timber have followed suit, and today forests of over a hundred million Eucalyptus trees have greatly changed the landscape in parts of the state of São Paulo; and the Eucalyptus population of the rest of Brazil totals at least another hundred million trees. The necessity of plantings for future use has been recognized in a recently enacted Brazilian law which requires that all large users of wood for fuel maintain reforestation projects, with annual plantings large enough to meet at least part of the needs.

The rate of growth of the best adapted species of Eucalyptus is amazing. Growth of six feet the first year is not unusual, with equally rapid gains in height the second and the third years. One instance of over five meters growth ($17 \pm$ ft.) was recorded of a seedling set out only six months before. Plant-

ings to be used for fuel are cut the seventh year, by which time the trunks are large enough to be used for fence posts. Trees fifteen years old are large enough for telegraph poles, and twenty-five year old trees yield railroad ties. The wood resists decay well, though it is usually chemically treated when used as posts or as railroad ties.

In recognizing Dr. Navarro's long fight to gain acceptance of the Eucalyptus in Brazil, the award of the Meyer Medal calls attention to a unique and outstanding chapter in plant introduction. Curiously enough it also may be a lead to a new use of Eucalyptus in this country. São Paulo has a climate much like Florida and other southeastern states, where reforestation is a serious problem. The species which Dr. Navarro has found best in Brazil should perhaps be tried in our own southeast, where even less spectacular growth might still make them very useful.

ROBERT COOK

CONFERENCE ON MOLECULAR STRUCTURE

A NUMBER of men of science interested in the structure of molecules¹ were invited by the Graduate School of Ohio State University to meet there for a conference during the last week of June. The topics discussed comprised the electronic structure of molecules; their rotational and vibrational motion; the application of our knowledge of these to the explanation and prediction of the thermodynamic behavior of gases and liquids; and the extension of our knowledge from atoms and diatomic molecules first to the simpler polyatomic molecules, and then to large, and even "giant" molecules. Reviews were made of our present information, and accounts were given of work in progress.

The electronic structure of atoms and of ions both in their normal and in their excited states and their behavior in collisions and in interaction with radiation are now very well understood. Mathematical difficulties in the application of quantum theory make exact prediction of their properties from theory alone hardly possible; but approximate methods, fitting into deductions from their observed spectra, make our knowledge nearly complete and leave no doubt that the theoretical laws are capable of explaining the observations.

For molecules the position is not so satisfactory. Exact quantitative theoretical predictions can only be made in the simplest cases; while theory predicts, for instance, that a neutral molecule made up of three hydrogen atoms would be unstable and could have only a transitory existence, but that the corresponding molecular ion with a single positive charge would be stable, requiring more

than 184 kilocalories of energy per mole, to break it up; this last result may be too small by 20 per cent. While the exact results obtained in the simplest cases, *e.g.*, the hydrogen molecule, H_2 , leave no doubt that the theoretical laws are adequate; in complicated cases only semi-quantitative, semi-empirical results, based partly on rough theoretical approximations, partly on observation, are possible.

Much work of this kind has been done by various authors especially for diatomic molecules for many of which the spectra have been for a long time adequately analyzed. This work has recently been extended to cover the properties of many molecules in detail, in excited as well as in normal states. Improvements in the dispersion of the spectra have recently led to the analysis of the electronic as well as the rotation-vibration spectra of some triatomic molecules, such as nitric oxide, NO_2 , and carbon dioxide, CO_2 , and it is probable that in the next few years we shall have information which will enable us to predict and explain in detail the kinetics of the interaction of many such molecules.

The most interesting recent work on rotation-vibration spectra has been on molecules showing peculiar effects; such as ammonia, NH_3 , for which we may regard the nitrogen atom as staying near the point of a pyramid on one side of the base composed of the three hydrogen atoms as long as the vibrations are of small amplitude, but as oscillating from one side to the other for vibrations of larger amplitude; and as some simple organic molecules, parts of which can rotate more or less freely relative to the rest; for example, the kind of internal motion shown by the molecules of alcohol, CH_3COOH , is now under discussion. Better knowledge of the internal motions is necessary in order to predict the thermodynamic behavior of these and of more complicated organic molecules.

¹ Professor David M. Dennison, University of Michigan; Professor Henry Eyring, Princeton University; Professor S. Herzberg, University of Saskatchewan, and Professor Robert Mulliken, University of Chicago, presented papers; Professor E. Bright Wilson, Harvard University, was at the last moment unable to come; his paper was read by Dr. Donna Price.



A SMALL PART OF A MODEL OF A RUBBER MOLECULE

THE GOAL OF MOLECULAR STRUCTURE THEORY, STILL FAR OFF, IS TO EXPLAIN IN DETAIL THE PROPERTIES OF KNOWN MOLECULES SUCH AS THAT OF RUBBER AND TO PREDICT THE PROPERTIES OF SIMILAR BUT UNKNOWN MOLECULES.

This behavior, which often can not easily be observed, may sometimes be important for industrial applications.

Satisfactory methods for computing the thermodynamic properties from pure theoretical predictions and from spectroscopic data for simple molecules have been in use for some time; the extension of these to the more complicated and to the larger molecules is now in progress, and it is a reasonable hope that before long we shall be able to predict very well any reactions between not too complicated molecules in the gaseous phase. Larger molecules, however, usually break up when they are vaporized; the important reactions are most often those occurring in the liquid phase. Until the last few years almost no progress had been made in the theory of liquids (apart from rather dilute solutions in which the solutes behaved nearly like gases). Good progress in this direction is now being

made; in particular the picture of a liquid as, thermodynamically, a mixture of about 86 per cent. solid and 14 per cent. gas, seems to give remarkably good results; this work can even be extended to large molecules of the form of long chains which can be regarded almost as worming their way past each other into the 14 per cent. of nearly empty space.

Progress in the next few years should be rapid. Improvements in spectroscopic equipment and technique are permitting the resolution and analysis of the spectra of more and more complicated molecules; and improvement in mathematical methods of applying theory enable explanations to be given and predictions to be made first on a rough semi-quantitative, semi-empirical basis; capable, however, of being refined, so far only for the simplest molecules, to give accurate quantitative results.

L. H. THOMAS

OHIO STATE UNIVERSITY

TELEPHONE BY-PRODUCTS

It is 65 years since the first sentence of speech was transmitted by telephone, and Alexander Graham Bell was granted the first patent for his unusual instrument. Six years later, the first conversation was held over long distance lines between New York and Boston, and in 1926 a public test was made of two-way transoceanic radio telephony between New York and London. All these achievements in the communica-

tions field occurred in March, and it was on the third of this month that Bell was born in Scotland in 1847.

By his invention, Bell not only gave the world one of its most important conveniences, but he also laid the foundation for the development of numerous other instruments.

One of the most interesting examples of the importance of the telephone is its tie-in with radio. "This program origi-

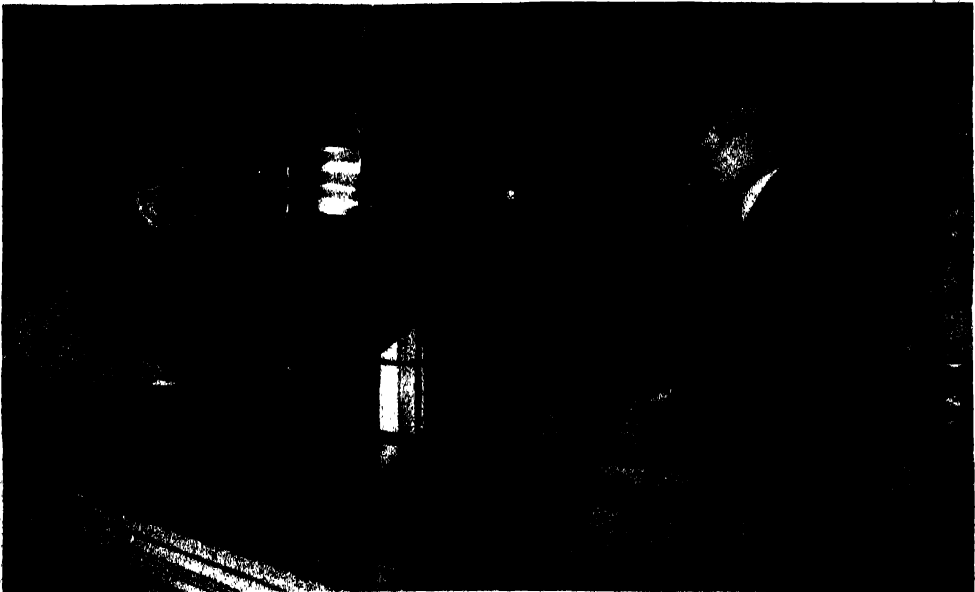
nated in our Hollywood studios" is a familiar phrase. Or one may hear a news round-up from many cities, such as New York, Washington, Chicago, San Francisco, all within fifteen minutes. The shift back and forth between these cities is so rapid it is unnoticeable. Quite naturally many listeners think that all the voices they hear are coming directly through the air to their radios, but that is not what happens. Actually these voices are relayed across the country over telephone wires to radio stations in different cities. Then they are relayed again to transmitters where they are put on the air. So the distance they come through the air to your radio depends on how far you live from the transmitter, which may be 5, 50 or 500 miles.

As an aid to the airplane industry, airway traffic control centers have been established in the larger airports of the country. In addition to telephone land-lines, radio-telephone circuits are kept very busy here because these centers regulate the movement of planes at the airport. There are also operators who

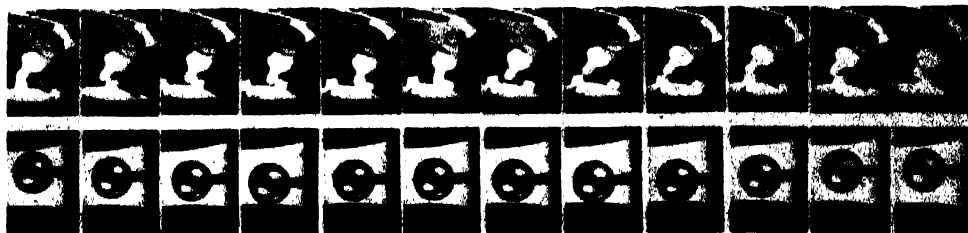
keep in constant communication with the control tower, the weather bureau, other airports and the dispatchers' offices of the different airlines.

A steel tape recorder for giving weather reports has been developed, which enables a person to learn the report merely by dialing a number in New York City, and listening to its message for 25 seconds. These reports, compiled by the New York Weather Bureau, are transmitted to the telephone office where they are recorded on machines. This device has greatly relieved the telephone operators at the Weather Bureau, for one machine can handle 30,000 consecutive calls a day. There is a similar method for obtaining the time; these services are also available in other large cities of the nation.

At both the San Francisco and the New York World's Fairs, there were two exhibits in the Bell Telephone building which were unusually popular. One was the "Voice Mirror" in which you talked into a telephone, and then listened to your words come back. These have been installed in many department stores to



APPARATUS FOR STUDYING THE CORONA OF THE SUN



PHOTOGRAPH OF RAPID MECHANICAL MOVEMENT

TAKEN WITH HIGH-SPEED CAMERA AT RATE OF 2,000 PICTURES A SECOND. *Above:* THE ACTION OF THE IMPULSE WHEEL, PAWL AND SNUBBING SPRING IN A TELEPHONE DIAL. *Below:* THE ACTION OF THE CLAPPER STRIKING THE GONG.

train the voices of their personnel, and singers find it helpful in learning their mistakes while practising the scales. The other was the hearing test equipment which over 1,500,000 visitors used in 1939. A survey was made of these tests, and there were interesting results as to the difference in hearing acuity between men and women, people of varied ages and those living in different localities. It is believed in the future such tests will be routine in physical examinations so that early symptoms of deafness will be recognized. Both of these machines are on permanent exhibition at the Franklin Institute in Philadelphia.

To achieve telephone privacy to all parts of the world, an apparatus has been devised which twists the vowels and consonants around, making a speech wholly unintelligible. To fully understand this strange method, let us trace the call a man is making from New York to London. He picks up the telephone and speaks his message as though he were just calling a neighbor. It then goes to the Overseas Transmitting Station in Lawrenceville, N. J., where it passes through the apparatus which scrambles the vowels and consonants, and is sent out on the air. In the office in London there is another device which unscrambles the inverted sounds into plain, understandable words.

While these experiments for the betterment of telephone service have been

going on, there have been times when the workers have made developments which can also be used in other branches of science, and seem at first to have little connection with the telephone industry.

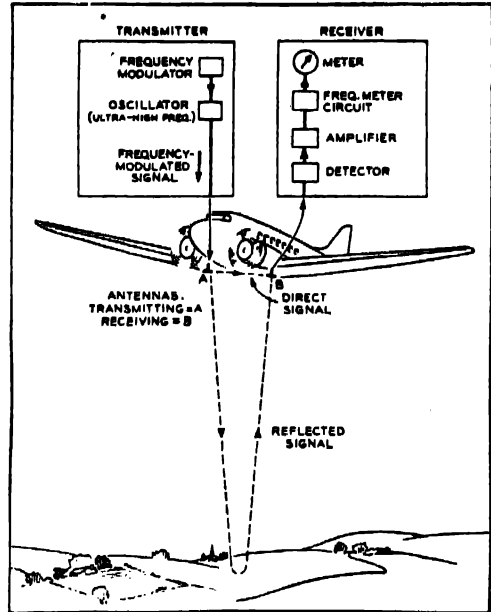
For a number of years, scientists have known that spots on the sun have interfered with clear radio reception, and have caused disturbances in other electrical industries. They wanted to see more of the corona—the atmosphere around the sun. The only time this could be seen was during a total eclipse. So the Bell Laboratories invented a machine called the Coronaviser, which was tried out last year at the Cook Observatory of the University of Pennsylvania. There will be even greater chances for making observations of the sun's atmosphere when this instrument is used with a powerful telescope on a mountain top, and plans for this are nearly completed at the McDonald Observatory on Mt. Locke in Texas.

Telephone researchers have contributed to the development of modern ultra-high speed photography. One camera, taking 4,000 pictures a second, has a small glass cube instead of a shutter. It rotates on a ball-bearing shaft between the lens and the film 1,000 times a second when used at high speed. For the intense lighting illumination which is needed, carbon arcs and tungsten lamps are used; liquid filters absorb nearly all the heat they radiate. This type of photography has been used

widely in many industries for analyzing defects in machinery, for studying vibrations in motors, and for investigating propeller design and performance in airplanes. Results have been decided in athletic events by this camera, and recently experiments have been made to study muscular and nervous reactions under varied conditions. After taking these motion pictures at such rapid speeds, they are projected at low speed.

To prevent planes from crashing into mountain tops because of miscalculation of their altitudes, the Terrain Clearance Indicator has been of much help to pilots. Previously all they had was an instrument which gave height above sea-level, and from this it was necessary to figure out the height above the ground. The indicator is really a radio altimeter which gives continuously a measurement of the distance between the plane and the earth. While flying over a city where there are skyscrapers and low buildings, there will be rapid fluctuations on the meter depending on the height of the obstructions. A very short radio wave is projected and reflected back and forth from the plane to the earth's surface or buildings. The reflected wave is made to differ from the projected wave, and the difference is indicated on a frequency meter. This instrument is also very useful as a position indicator when a pilot is approaching an airport which is near a large building.

In the medical field, there have been two noteworthy developments. The artificial larynx has restored the power of speech to many people who were either mutes or who have lost the use of their vocal cords. The apparatus consists of a thin metal "reed" attached to a rubber tube at one end with a small opening at the other. This metal "reed" is set in motion when the person blows air from his lungs through the apparatus. The vibration stops and starts the flow of air, and makes a series of sound



METHOD OF OBTAINING HEIGHT
USING THE TERRAIN CLEARANCE INDICATOR.

waves similar to those made by the human vocal cords. He goes through the usual motions of speaking with his tongue and lips, and the speech sounds are made by the resonating action of the mouth, throat and nasal cavities. By faithful practice, a person can become an expert at using this device and once more function as a normal, independent citizen. The other is a portable stethoscope which fits into a small case just a foot long, and can be carried around by the general practitioner. With this instrument the sound of the heartbeat can be increased 100 times more than with the acoustic stethoscope. It consists primarily of a magnetic "pick up" and receiver and a two-stage amplifier operated by dry batteries. It is valuable for doctors whose hearing is impaired, and for demonstration purposes when the physician is explaining to students the causes and differences in the heartbeats. Also it becomes an aid in prescribing for the treatment of those suffering from symptoms of heart disease.

EMILY DUANE WALLACE

FEDERAL OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

COORDINATION of all scientific activities concerned with national defense is the objective of the new Office of Scientific Research and Development which has been created within the Office of Emergency Management by executive order of President Roosevelt. Under the directorship of Dr. Vannevar Bush, president of the Carnegie Institution of Washington and until now chairman of the National Defense Research Committee, the new organization will serve as liaison agency for a number of scientific groups which have hitherto worked independently of each other, reporting directly to the President.

Funds for the promotion of scientific research programs for the production of new weapons and defense materials and methods, and for medical research programs having defense value, are provided by Congressional appropriation. The new Office of Scientific Research and Development is authorized to "initiate and support" such programs. This is a long step forward, for similar bodies set up during previous national emergencies have had only advisory capacity, and could not undertake research programs or other activities on their own initiative. Dr. Bush indicated his intention to "lean heavily" upon these older advisory bodies, particularly the National Academy of Sciences and the National Research Council.

In carrying on the activities authorized by the new executive order, one of the principal disbursing and action agencies will be the already existing National Defense Research Committee, of which President James B. Conant has been appointed chairman, succeeding Dr. Bush. It is understood that Dr. Conant's duties will be such that he can carry them out without neglecting his work as a university president.

Other agencies already functioning that will report to the President through Dr. Bush include the National Advisory Committee for Aeronautics, the National Inventors Council and the Health and Medical Committee established by order of the Council of National Defense. Distinctly defense activities of established bureaus in government departments, such as the Bureau of Mines and the National Bureau of Standards, will also come within the purview of the new Office of Scientific Research and Development.

Somewhat similar action was taken in Britain some time ago, when a single coordinating body was appointed to act as liaison agency between the government and about half-a-hundred research groups in various British defense organizations, both military and civil.

Close cooperation is provided for, between British and American research bodies. Britain already has an office in this country, and when Dr. Conant was in England recently he set up a similar office there, which is now taken over by the new Office of Scientific Research and Development. British scientists have requested their American colleagues to take over certain basic scientific research, especially in the field of medicine, in order that they may devote their attention more intensively to immediately pressing practical problems.

The new Office of Scientific Research and Development will also mesh closely with the Office of Production Management under William S. Knudsen and the Office of Civilian Defense under Fiorello LaGuardia. The function of Dr. Bush's organization for them, as for the Army and Navy, will be to find useful scientific methods, devices and materials, which these agencies of application can take over, produce and put into use.—*Science Service.*

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1941

CHEMICAL PROPERTIES OF VIRUSES

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Six years ago over a hundred viruses were recognized, yet it would have been virtually impossible to write then on the present subject, for at that time practically nothing was known about the chemical properties of viruses. These agents, which are responsible for untold millions of illnesses and deaths amongst people, animals and plants, were recognized only by means of the diseases which they caused, diseases such as smallpox, parrot fever, yellow fever, St. Louis encephalitis, poliomyelitis, horse encephalomyelitis, foot-and-mouth disease of cattle, louping ill of sheep, hog cholera, rabies, dog distemper, fowl pox, certain types of tumorous growths in fowls and other animals, jaundice of silkworms and various yellows and mosaic diseases of plants. The general nature of the agents responsible for such diseases was a matter of much conjecture. When placed in certain living cells, these agents could multiply, mutate or undergo variation to form new strains, and induce immunity. They seemed to have many of the properties of very small living organisms such as the bacteria; yet, unlike most bacteria, they were too small to be seen by means of the ordinary microscope and could not be induced to multiply in the absence of living cells. They were mysterious, invisible somethings which, in the absence of living cells, appeared as harmless and

as lifeless as pebbles on the beach, but which, even after years of inactivity, were ready to spring into action and cause disease and death when introduced by chance or by design into certain living cells. By virtue of their ability to mutate or form variants, they were able to change and adapt themselves to new surroundings and conditions and thus not only to retain but to enlarge their place in a changing world. The fact that the viruses were recognized only by means of the diseases which they caused and the fact that these diseases were becoming of increasing importance only served to add to the mantle of mystery which surrounded them and to intensify the challenge which they presented.

In 1935 a tangible characteristic material possessing virus activity was isolated from Turkish tobacco plants diseased with tobacco mosaic virus and made available for chemical study. The material, which appeared to be a nucleoprotein of enormous size possessing quite distinctive properties, was obtained from every lot of diseased Turkish tobacco plants examined. The same material was obtained from various, in some instances unrelated, species of mosaic-diseased plants. Slightly different, although closely related, nucleoproteins were isolated from plants diseased with strains of tobacco mosaic virus. The purified preparations possessed proper-



FIG. 1. TOBACCO MOSAIC VIRUS
EACH NEEDLE-LIKE CRYSTAL CONTAINS MANY
MOLECULES OF VIRUS AND HAS BEEN REFERRED TO
AS PARA-CRYSTALLINE, SINCE X-RAY DATA INDICATE
A LACK OF INTERMOLECULAR REGULARITY IN
THE DIRECTION OF THE LENGTH. MAGNIFICATION
× 753.

ties which were characteristic, not of the hosts in which they were produced, but of the virus or virus strain. An unexpected finding was that mosaic-diseased Turkish tobacco plants may contain as much as one part per 500 of the high molecular weight nucleoprotein. The amount of material isolable varied in other cases and appeared to depend upon the host and the strain of the virus, and in some instances was only a small fraction of the amount obtainable from mosaic-diseased Turkish tobacco plants. To date all attempts to separate tobacco mosaic virus activity from the nucleoprotein have failed and the material, which can be obtained in the form of long thin paracrystalline needles (Fig. 1), has come to be regarded as crystalline tobacco mosaic virus. The material provided the first information regarding the

general nature and chemical makeup of this virus and, although its exact nature was and remains a debatable matter, its isolation removed some of the mystery surrounding the general nature of viruses and served as an incentive for the search for similar materials in the case of other virus diseases.

The isolation of crystalline tobacco mosaic virus was followed by the preparation from various virus-diseased tissues of over 20 crystalline or amorphous materials possessing some of the properties of the respective viruses or virus strains. In not every case has it been proved that the material is essentially pure and consists of virus. However, in several cases it has been proved beyond a reasonable doubt that the materials consist of the respective viruses in an essentially pure state, and in no instance has virus activity been obtained in the absence of the characteristic material. Due chiefly to our older ideas of the nature of viruses, the crystallinity of some of the purified preparations may appear at first as a rather spectacular property; yet, if these materials are considered as proteins, crystallinity becomes an expected rather than an unexpected property, for many proteins are known to be crystallizable. Careful and mature consideration will reveal that crystallinity or the lack of crystallinity is of no special importance in connection with the purity or general nature of a material, but is important chiefly because it makes it possible to obtain certain solubility and x-ray data which would otherwise be unobtainable.

There is not sufficient space for a detailed discussion of the chemical properties of all the preparations of purified viruses and, in order to provide you with an idea of their general chemical properties, I shall devote most of the text to the two viruses which have been extensively investigated from this standpoint, namely, tobacco mosaic and tomato

bushy stunt viruses. These are typical viruses with respect to the essential and recognized characteristics of a virus; yet it must be admitted that each has certain special properties which make it an unusually favorable material for experimental work. Thus, tobacco mosaic virus is among the most stable of all viruses and reaches a concentration in Turkish tobacco plants which is far greater than that reached by most viruses in their respective hosts even under the most favorable conditions, and bushy stunt is the only virus which has been obtained in the form of large rhombic dodecahedral crystals (Fig. 2). However, there is no more reason for regarding these viruses as atypical because of such special properties than for regarding vaccine virus as atypical because of its unusually large size or foot-and-mouth disease virus as atypical because it is the smallest of all viruses. Tobacco mosaic and bushy stunt are plant diseases, and it has been argued that the viruses of plants differ fundamentally from those of animals and, hence, that information gleaned from studies on plant viruses has but little significance in connection with animal viruses. This argument was based chiefly on the failure of plant viruses to grow in animals and of animal viruses to grow in plants. However, because there is no difference in the fundamental virus properties, I have always considered this to be an erroneous viewpoint. Within the past few years, Fukushi secured strong evidence that rice dwarf disease virus multiplies in its insect vector, and Kunkel and more recently Black have obtained experimental evidence which demonstrates beyond a reasonable doubt that aster yellows virus can multiply in its insect vector. The growth of a plant virus in an animal provides further evidence in support of the conclusion that there is no fundamental difference between the viruses of plants and those of

animals. Different viruses must of necessity differ in certain of their properties, and a composite picture of viruses as a group will not be obtained until many viruses have been studied.

Tobacco mosaic virus appears to be a conjugated protein containing about 95 per cent. protein and 5 per cent. nucleic acid. The latter has been found to contain uridylic acid, guanine, cytosine and adenine, and to give a test for a pentose but not for a desoxypentose and, hence, appears to be of the yeast rather than of the thymus nucleic acid type. Bushy stunt virus appears to contain about 83 per cent. protein and 17 per cent. of a nucleic acid of the same kind as that found in tobacco mosaic virus. Tobacco ring spot virus contains 40 per cent. nucleic acid, the highest percentage yet found in a virus. This is also of the yeast nucleic acid type, but the elementary bodies of vaccinia and of psittacosis have been found to give a test characteristic of thymus nucleic acid. With the exception of a bacteriophage preparation obtained by Kalmanson and Bronfenbrenner and considered to be a simple protein, all the purified virus preparations so far obtained have been at least as

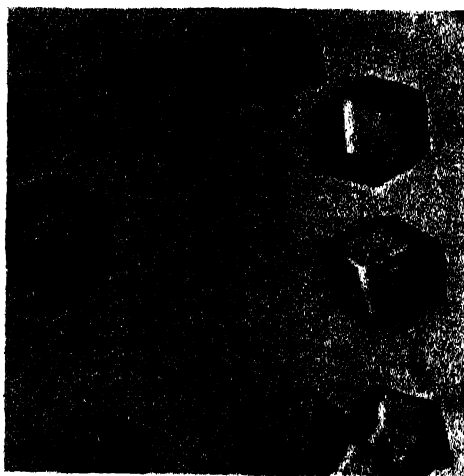
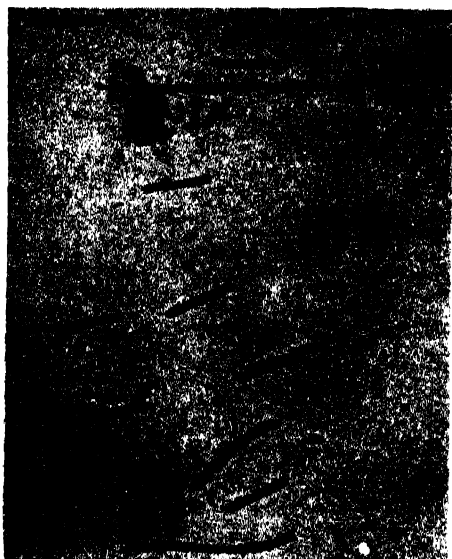


FIG. 2. TOMATO VIRUS
CRYSTALS OF TOMATO BUSHY STUNT VIRUS. MAGNIFICATION $\times 209$.



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FIG. 3. TOBACCO VIRUS MOLECULES
 MICROGRAPH OF MOLECULES OF TOBACCO MOSAIC
 VIRUS TAKEN BY MEANS OF THE RCA ELECTRON
 MICROSCOPE. MAGNIFICATION $\times 34,000$.



G. A. Miller
FIG. 4. ELECTROPHORETIC PATTERN
 SHOWN BY A 0.1 PER CENT. SOLUTION OF TOBACCO
 MOSAIC VIRUS. A AND D REPRESENT THE ASCEND-
 ING AND DESCENDING BOUNDARIES AT THE START
 OF THE EXPERIMENT. A' AND D' REPRESENT THE
 SAME BOUNDARIES AT THE END.

complex as a nucleoprotein. This fact may eventually prove of prime importance, for it may be recalled that chromosomes appear to consist almost exclusively of nucleoprotein. Some viruses appear to contain in addition some carbohydrate, others lipid, and still others appear to be so complex that they may be indistinguishable from bacteria in composition. The distribution of amino acids in the protein component of tobacco mosaic virus has been studied, and at present only the apparent absence of histidine and the lack of a preponderance of arginine and of other known basic amino acids are noteworthy. The complete amino acid distribution in strains of this virus and in other viruses has not been determined as yet, although such studies are in progress and may provide a clue to the reason for the specificity of viruses and possibly a means for distinguishing not only between viruses but also between the strains of a virus. For example, with Dr. Knight it has already been found that the amounts of certain aromatic amino acids vary with the strain of the virus. Analysis of 12 preparations of tobacco mosaic virus indicated the presence of 3.8, 4.5 and 6.0 per cent. of tyrosine, tryptophane and phenylalanine, respectively, with maximum deviations of ± 0.1 per cent. for the tyrosine and ± 0.2 per cent. for the tryptophane and phenylalanine values. The corresponding values in the case of the Holmes ribgrass strain of tobacco mosaic virus were 6.4, 3.5 and 4.3 per cent. and 3.8, 1.4 and 10.2 per cent. in the case of the closely related cucumber mosaic virus 4. These results are of considerable importance, since they show that the mutation of tobacco mosaic virus with the formation of a new strain which in turn causes a new disease may be accompanied by changes in the amino acid composition of the virus. The fact that the phosphorus content of the different strains was approximately the



FIG. 5. ABSORPTION PICTURES OF TOBACCO MOSAIC VIRUS
SHOWING TWO SHARP SEDIMENTING BOUNDARIES.

same may be taken as an indication of the absence of significant quantitative differences in the nucleic acid component of the strains. Because of the close similarity between the properties of viruses and those of the bearers of heredity, it is obvious that an extension of this work should provide information of a fundamental nature regarding the structural changes involved in the mutation within chromosomes. The nature of the structural alterations which must be responsible for changes in the virulence of a virus may also be elucidated.

Tobacco mosaic virus contains 50 per cent. carbon, 7 per cent. hydrogen, 16

per cent. nitrogen, 0.6 per cent. phosphorus and 0.2 per cent. cysteine sulfur. It has an isoelectric point at pH 3.5, a density of 1.37, and at a concentration of about 2 mg per cc a sedimentation constant of 174×10^{-13} cm in unit centrifugal field and a diffusion constant of 3×10^{-8} sq. cm. per sec. It has been estimated by indirect methods that the particles of the virus are remarkably anisometrical and are about 400 m μ in length and about 12 m μ in diameter. Recently, by direct observation by means of the electron microscope, Dr. Anderson and I found that most of the particles in a dilute solution of the virus are about

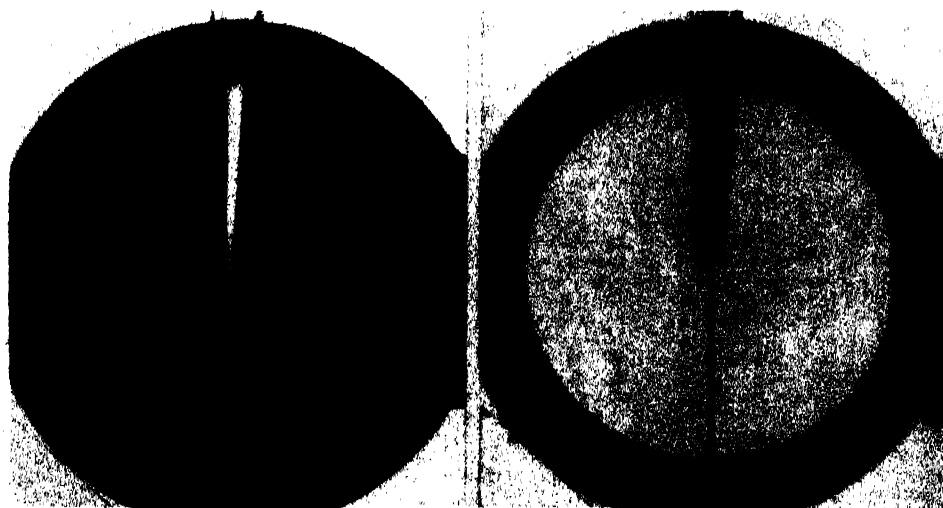
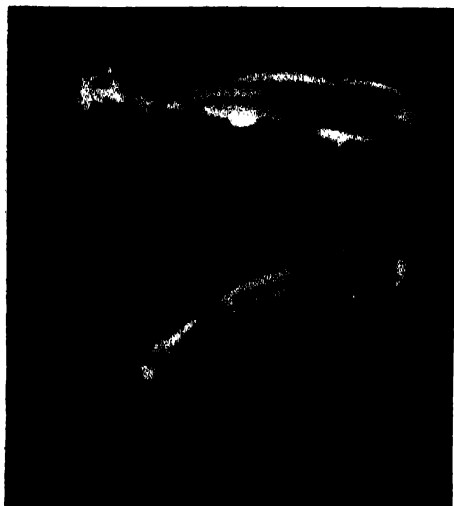


FIG. 6. DOUBLY REFRACTING STREAM OF TOBACCO MOSAIC VIRUS
FLOWING FROM A PIPETTE. *Left*: PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES ARRANGED SO THAT EACH VIBRATION DIRECTION OF THE POLAROID PLATES MAKES AN ANGLE OF 45° WITH DIRECTION OF FLOW. *Right*: SAME SYSTEM PHOTOGRAPHED BETWEEN PARALLEL POLAROID PLATES.

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FIG. 7. FISH IN VIRUS SOLUTION

FISH SWIMMING THROUGH A 0.7 PER CENT SOLUTION OF TOBACCO MOSAIC VIRUS. PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES. LIGHT AREAS SHOW DOUBLE REFRACTION DUE TO ORIENTATION OF ROD-LIKE MOLECULES OF VIRUS CAUSED BY CURRENT SET UP BY MOVEMENT OF FISH.

280 μ in length and about 15 μ in diameter (Fig. 3). Several kinds of evidence indicate that the molecular weight of tobacco mosaic virus is about 50 millions. The value of 17 millions, which was estimated several years ago when the asymmetry was unknown and which was based on an assumed asymmetry constant of 1.3, is incorrect. However, it is possible that different strains of tobacco mosaic virus may have different molecular weights, for the sedimentation constant of the aucuba mosaic strain is measurably larger than that of tobacco mosaic virus and the x-ray data indicate that the molecules of the former have the same diameter as that of the molecules of tobacco mosaic virus. Furthermore, Melchers and coworkers, in a study by means of the electron microscope, found the molecules of the two strains of tobacco mosaic virus with which they worked to have particle lengths of about 190 μ and 140 μ .



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FIG. 8. OBJECT IN VIRUS SOLUTION

OBJECT MOVING FROM LEFT TO RIGHT THROUGH A 0.7 PER CENT SOLUTION OF TOBACCO MOSAIC VIRUS. PHOTOGRAPHED BETWEEN CROSSED POLAROID PLATES. LIGHT, DOUBLY REFRACTING AREAS SHOW NATURE OF CURRENTS CAUSED BY MOVING OBJECT.

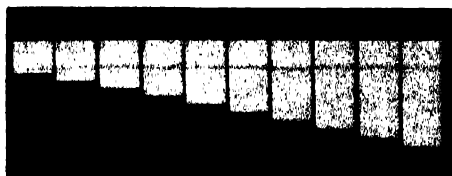


FIG. 9. SEDIMENTING BOUNDARY

ABSORPTION PICTURES SHOWING SEDIMENTING BOUNDARY OF TOMATO BUSHY STUNT VIRUS.

Tobacco mosaic virus gives a sharp boundary and migrates at a uniform rate in the Tiselius electrophoresis apparatus (Fig. 4). When carefully prepared, the virus gives a sharp boundary in the ultracentrifuge, but on treatment with salt at room temperature some of the particles appear to aggregate end-to-end to give a preparation which shows two boundaries in the ultracentrifuge. The second more rapidly sedimenting boundary is due apparently to a component formed by the end-to-end aggregation of pairs of molecules (Fig. 5). Further aggregation yields a very inhomogeneous product which shows a very broad boundary in the ultracentrifuge. The sedimentation constant of tobacco mosaic virus has been found to vary with the concentration, due apparently to interparticle forces which become of considerable magnitude in concentrated solutions. Solutions of tobacco mosaic virus

exhibit strong double refraction of flow and electrical double refraction, the former being due to the rod-like shape of the particle and the latter to the particle being asymmetrically charged, either permanently or as a result of the electrical field (Fig. 6). The fact that tobacco mosaic virus shows strong double refraction of flow may prove of considerable importance in apparently unrelated fields, for if necessary the virus could be prepared in pound lots or in larger amounts and used to study the flow currents in apparatus such as pumps and hydraulic rams or the nature of the flow when boats or projectiles move through a liquid (Figs. 7 and 8). Moderately concentrated solutions of the virus, when allowed to stand, separate out into two distinct layers, the lower of which is

spontaneously doubly refracting and the upper of which shows double refraction only when caused to flow. Pellets of the virus obtained by ultracentrifugation are doubly refracting. The strains of tobacco mosaic virus and cucumber mosaic 3 and 4 viruses have properties somewhat similar to those just described. Latent mosaic virus of potato has a rod-like shape and appears to be even more asymmetrical than tobacco mosaic virus. The layering phenomenon, the change in sedimentation constant with concentration, and certain of Bernal's x-ray studies, of Lauffer's observations on the electro-optical effect and of Frampton's studies on the thixotropic character of tobacco mosaic virus indicate that in concentrated or moderately concentrated solutions there are interparticle forces



FIG. 10. MIXTURE OF TOBACCO MOSAIC VIRUS WITH NORMAL RABBIT SERUM

THE CONTAMINATING BACTERIUM SERVES TO GIVE A GOOD IDEA OF THE RELATIVE SIZE OF THE MOLECULES OF VIRUS. ELECTRON MICROGRAPH WITH MAGNIFICATION \times CA 37,000.



FIG. 11. TOBACCO VIRUS WITH ANTI-TOBACCO VIRUS RABBIT SERUM
AN ELECTRON MICROGRAPH WITH MAGNIFICATION \times CA 13,700.

which are effective over large distances. Although in the past the existence of such long-range forces has been denied for theoretical reasons, Langmuir and Levine independently have recently shown that there are in fact good theoretical grounds for their existence. The demonstration of the existence of forces acting between molecules hundreds of \AA units apart, and their acceptance from the standpoint of theory alone, may prove of great importance in connection with our theories of virus reproduction and other intracellular events such as the duplication of chromosomes.

The carbon, hydrogen and nitrogen contents of bushy stunt virus are about the same as those of tobacco mosaic virus. However, the phosphorus and sulfur contents of 1.5 and 0.4 to 0.8 per cent., respectively, are considerably larger than those of tobacco mosaic virus. Bushy stunt virus has a density of 1.35, a sedimentation constant of 132×10^{-13} and a

diffusion constant of 1.15×10^{-7} . A molecular weight of about 8 million and a particle diameter of about 26 $\text{m}\mu$ may be calculated from these constants. Solutions of bushy stunt virus do not show double refraction of flow and the pellets obtained on ultracentrifugation are isotropic. The particles of the virus appear to be essentially spherical in shape. The purified preparations are homogeneous when examined in the ultracentrifuge or the Tiselius electrophoresis apparatus (Fig. 9). Bushy stunt virus does not appear to be susceptible to the peculiar aggregation which seems to be a characteristic of the rod-shaped viruses and, unlike the latter, the sedimentation constant is almost independent of the concentration. Several other viruses have been found to be essentially spherical in shape. Among these are alfalfa mosaic virus, which has a molecular weight of about 2 million and a diameter of about 16 $\text{m}\mu$, and the Shope rabbit papilloma

virus, with a molecular weight of about 25 million and a diameter of about 40 m μ . The elementary bodies of vaccinia have a diameter of about 225 m μ . There is, therefore, a group of rod-shaped viruses and a group of viruses which are essentially spherical in shape, although with the development of more precise techniques some of the latter may be found to be definitely ellipsoidal in shape. It should be emphasized that each virus has a shape and a size which appear to be quite definite and characteristic, regardless of the conditions or the host in which the virus is produced. However, neither this statement nor the statements relative to the homogeneity of virus preparations in the ultracentrifuge or electrophoresis apparatus are meant to imply that all the particles in a given virus preparation are exact replicas. The fact that variants continually arise during the production of virus would always insure the presence in purified preparations of a small amount of closely related although slightly different particles. There is other evidence, such as that obtained by Loring in solubility studies on tobacco mosaic virus, which indicates that the purified virus preparations are not absolutely homogeneous chemically but consist of a family of very closely related structures. The general situation may not be far different from that which is now known to exist in the case of even very simple structures, such as sulfur, nitrogen and hydrogen, where families of isotopes are the rule rather than the exception. In this connection, it may be stated that the problems and relationships which obtain with the tremendous virus structures are not well clarified at present. However, from a practical standpoint, there has been little difficulty as yet, for there are several instances in which, according to present techniques, there is a very high degree of chemical homogeneity.

Tobacco mosaic, bushy stunt and other viruses which have been obtained in purified form are good antigens. It is necessary, however, to inject animals



FIG. 12. SEDIMENTATION DIAGRAM OF A MIXTURE OF TOMATO BUSHY STUNT VIRUS WITH ANTI-TOBACCO MOSAIC VIRUS RABBIT SERUM. AT THE CENTRIFUGAL FORCE USED, THE RIGHT-HAND PEAK, WHICH IS DUE TO THE SERUM PROTEIN BOUNDARY, IS PRACTICALLY STATIONARY, WHEREAS THE OTHER PEAK, WHICH IS DUE TO THE BUSHY STUNT VIRUS BOUNDARY, GRADUALLY MOVES TO THE LEFT. THE SEDIMENTATION CONSTANT OF THE BUSHY STUNT VIRUS IS ESSENTIALLY UNCHANGED, INDICATING LACK OF REACTION WITH THE ANTISERUM.



T. F. Anderson and W. M. Stanley

FIG. 13. MIXTURE OF VIRUSES

ELECTRON MICROGRAPH OF A MIXTURE OF TOBACCO MOSAIC AND BUSHY STUNT VIRUSES WITH ANTI-BUSHY STUNT VIRUS RABBIT SERUM. THE MOLECULES OF TOBACCO MOSAIC VIRUS ARE UNAFFECTED; THOSE OF THE BUSHY STUNT VIRUS ARE CLUMPED TOGETHER. MAGNIFICATION \times CA 14,000.

with the viruses, for antibodies do not appear to be produced in plants. This may be due to the nature of plants for, despite much effort, no conclusive proof of the existence of antibodies in plants has been obtained, although Wallace secured some suggestive results with curly top virus. The serum of a rabbit injected with tobacco mosaic virus gives a specific precipitate with tobacco mosaic virus and specifically neutralizes tobacco mosaic virus activity. This reaction has been studied with Dr. Anderson by means of the electron microscope and the ultracentrifuge. Electron micrographs of a mixture of virus and normal rabbit serum show virus particles of normal size, indicating little or no adsorption of particles from normal serum on the virus molecules (Fig. 10). The sedimentation constant of tobacco mosaic virus is essentially unchanged in mixtures containing normal rabbit serum or antisera to bushy stunt, ring spot or latent mosaic viruses. However, electron micrographs of a mixture of tobacco mosaic virus and tobacco mosaic virus antiserum from rabbits show particles about 60 μ wide, about 300 μ long and having fuzzy profiles (Fig. 11). The increase in particle width and the fuzzy appearance are regarded as indicating that the ends of asymmetrically shaped molecules from the serum react specifically with the virus molecules. No reaction between

anti-tobacco mosaic virus serum and bushy stunt virus was demonstrable either by means of the electron microscope or the ultracentrifuge (Fig. 12). Bushy stunt virus is, however, specifically precipitated by its own antiserum (Fig. 13). In general, a serological relationship may be demonstrated between different strains of the same virus, but not between different viruses. However, Bawden and Pirie have found that a serological relationship exists between tobacco mosaic and cucumber mosaic 3 and 4 viruses. This fact and the fact that other properties of these viruses are very similar may indicate a common origin for these viruses. Bawden and Pirie also noted that the precipitates of rod-shaped viruses with their antisera resembled those obtained with bacterial flagellar antigens, whereas those of the symmetrically shaped bushy stunt virus resembled those with somatic antigens. Tobacco mosaic virus has been found not anaphylactogenic by the Schultz-Dale technique and only weakly anaphylactogenic when tested *in vivo*.

Viruses are inactivated when subjected to excessive amounts of acid, alkali, oxidizing agents, formaldehyde, urea, ultraviolet light or heat. In general, the rate and the amount of the inactivation vary with the virus and with the severity of the treatment. Tobacco mosaic virus is stable between about pH 2 and pH 8. At more acid or more alkaline reactions the nucleoprotein is denatured and broken up into material of low molecular weight, and the virus activity appears to be irreversibly lost. There is some evidence that the virus first breaks into fairly large pieces and these then continue to break up into progressively smaller pieces, but more data will be required before an exact picture of the process may be obtained. The disintegration of virus in urea provides another interesting process for study. In 6 M urea and 0.1 M phosphate buffer at pH 7,

tobacco mosaic virus is rapidly disrupted, with appearance of free sulfhydryl groups, into low molecular weight protein components which contain no nucleic acid, exhibit no double refraction of flow, are insoluble in dilute buffers, and possess no virus activity. The rate of the disintegration varies widely with the concentration of urea, the concentration of electrolyte, the type of electrolyte, the hydrogen-ion concentration and the temperature. The bonds which hold the component parts of the virus together appear to be released and satisfied by those of the urea, for the virus structure literally flies apart. It is obvious that studies on these split products should reveal information concerning the nature of the components making up the virus and perhaps furnish a clue as to the mode of synthesis of the virus. Materials similar in structure to urea, such as guanidine, as well as apparently unrelated substances, such as sodium dodecyl sulfate, also cause disintegration of the virus. Enzymes have been found to cause the breakup of certain viruses. Neither tobacco mosaic nor bushy stunt virus is split by trypsin, but this enzyme causes the rapid hydrolysis of alfalfa mosaic virus. Tobacco mosaic virus appears to be digested slowly by pepsin, although the rate of hydrolysis is much slower than might have been anticipated. All viruses appear to be denatured by heat, and the temperature at which denaturation occurs depends upon the virus and to some extent upon conditions such as the hydrogen-ion concentration and the kind of salts present.

In the heat and other types of denaturation reactions that have just been described, there is a more or less complete disintegration of the virus structure and the products which are formed do not have the properties which characterized the intact virus. They are of low molecular weight, do not react serologically with antiserum to virus, and do not induce the

formation of antibodies which neutralize virus. It has been found possible, however, to inactivate viruses without such a complete disintegration of structure. When tobacco mosaic virus is treated with mild oxidizing agents, formaldehyde, nitrous acid or ultraviolet light, the properties of the resulting materials are, with the exception of virus activity, very similar to those of the intact virus. For example, the size and shape are not measurably affected, the materials give a precipitin reaction with antiserum to active virus, and, perhaps most important, the injection of the inactive materials gives rise to the production of antibodies which will specifically neutralize tobacco mosaic virus activity. It appears that these treatments cause no great change in the general topography of the virus structure, but bring about changes that are very small with respect to the structure as a whole but which are nevertheless sufficiently definite to cause the loss of virus activity. This fact may be quite important in connection with efforts to protect ourselves against the devastating effects of virus diseases. As you may know, in the three general methods of protection which are now employed, active virus plus immune serum, active virus usually of a strain that will cause a less severe disease, or inactivated virus is used to secure immunization. The second method is used extensively and successfully in the protection against smallpox, yellow fever and certain other virus diseases, and the third method, which has proved less satisfactory, has been used with claims for success for many viruses such as hog cholera, rinderpest, dog distemper, influenza, and others. It is now being widely employed in the case of equine encephalomyelitis virus. In the second method, the production of a strain which will cause an innocuous disease but which will immunize against virulent strains is most important. In the third method, the produc-

tion of an inactivated virus which will, upon injection, immunize against active virus is most important. It seems likely that many of the failures to achieve the latter result have been due to the use of methods of inactivation which cause too great a change in the structure of the virus. In our studies of the viruses which we have purified, we have found that the same procedure which will inactivate a given virus without causing widespread loss of structure and loss of characteristic antigenic properties will cause the complete disintegration and loss of characteristic antigenic properties of another virus. It is obvious, therefore, that it is of extreme importance that viruses be obtained in purified form and studied so that for each virus a method may be evolved for inactivating the virus without destroying its immunizing potency. The change in structure that results in inactivation need not necessarily be very great, and it may even be reversible. For example, we have found that the inactivation resulting from the addition of formaldehyde to tobacco mosaic virus may be reversed and active virus once again prepared from the inactive material. The fact that this reaction may be reversed is some indication that a major change in structure is not involved.

Closely related to the general problem of inactivating viruses with the least possible change in structure are the studies on ways and means of producing the less virulent strains of a virus which are so important in connection with the second general method of immunization. So far, the production of less virulent strains which have proved of great practical importance has been achieved by the simple expedient of passing the virus through another host. Thus, a strain of virus which will protect against smallpox may be obtained by infecting a calf with smallpox virus and reisolating the virus produced after several passages in calves.

A useful strain of yellow fever virus was secured in a similar manner by Theiler by passage through mouse brains. The change in environment during the production of virus in the second host apparently results in the production or selection of a strain of virus which is much less virulent in the first host. Practically nothing is known as to why a less virulent strain is prepared or of the change in structure which must be involved. However, it does not appear unreasonable to expect that definite chemical reactions which result in a change in the structure of a given virus without causing inactivation will achieve the same result and yield strains of the virus, some of which may cause a less virulent disease and be useful for immunization against virulent strains. Leaves diseased with different strains of tobacco mosaic virus are shown in Figure 14. Some progress has been made in studies on methods for changing the chemical structure of tobacco mosaic virus without causing a loss of virus activity. Dr. Anson and I found that the sulfhydryl groups of the virus can be abolished by reaction with iodine and the altered virus still retains its normal biological activity as shown by the number of lesions it causes on *Nicotiana glutinosa* plants and by the characteristic disease produced in Turkish tobacco plants. Since the virus isolated from the latter plants had the normal number of sulfhydryl groups, the structural change caused by iodine treatment was not perpetuated in subsequent generations of the virus. Because of the possibility that the iodine-altered virus might be reduced to normal virus within the plant cells, other reactions of a less readily reversible nature were sought. With Dr. Miller it was demonstrated that most of the amino groups of tobacco mosaic virus may be acetylated by means of ketene without causing a measurable change in the specific virus activity or in the nature



C. A. Knight and J. A. Carlile

FIG. 14. DISEASED TURKISH TOBACCO LEAVES

AFFLICTED WITH DIFFERENT STRAINS OF TOBACCO MOSAIC VIRUS. T. M. V. = TOBACCO MOSAIC VIRUS. Y. A. = YELLOW AUCUBA MOSAIC VIRUS. G. A. = GREEN AUCUBA MOSAIC VIRUS. M. = A MASKED STRAIN OF TOBACCO MOSAIC VIRUS. THIS LEAF IS PRACTICALLY INDISTINGUISHABLE IN APPEARANCE FROM A NORMAL TURKISH TOBACCO LEAF, YET CONTAINS MUCH VIRUS.

of the disease produced in Turkish tobacco plants. Since it seems unlikely that the acetyl groups are removed on inoculation of the modified virus to plants, the fact that the virus produced in such plants contains the normal amount of amino nitrogen may be regarded as evidence that the modified virus actually brings about the production of normal or unmodified virus. Similar results have been obtained with virus modified by the introduction of about 3,000 phenylureido groups per molecule of virus by means of reaction with phenylisocyanate. These results demonstrate that a large portion of the surface structure of the virus may be changed without interfering with the basic reaction of virus reproduction. Other reactions are being studied in an effort to secure modifications that will be perpetuated in subsequent generations of the virus. The purposeful production of new and useful strains by chemical means is one of the major problems in the virus field and its solution will be of tremendous importance not only from a practical standpoint but also in connec-

tion with the larger and fundamental problem of the nature of virus activity. The latter problem, the inactivation problem and the problem of induced mutation are all so closely related that it is impossible to attack one without attacking the others and simultaneously fundamental problems in other fields, such as the origin of a cancerous cell, the duplication of a chromosome, the mutation of a gene, and even perhaps the nature of that ill-defined something called life.

Although we do not know how viruses originate, reproduce or mutate, we have learned much about their chemical properties during the past five years. We know that for every reasonably stable virus which has been investigated there is a definite, characteristic, high molecular weight material which is at least as complex as a nucleoprotein. The properties of these materials may differ widely, although in each instance the size, shape and chemical and other properties are the same regardless of the source of the virus. The properties of materials from strains of the same virus are similar

although slightly different. The amounts of the materials which may be obtained differ tremendously and appear to depend upon the host and the virus or virus strain. The materials appear to be reasonably homogeneous when carefully prepared. Many different types of experiments have demonstrated a direct correlation between the integrity of structure of a given material and its virus activity. Because of this and because it has not been found possible to separate virus activity from these materials, there is reason to believe that they are the viruses. They appear to have the properties of molecules and in addition the property of virus activity, a kind of property usually assigned to organisms and one which has not heretofore been ascribed to molecules. Some may wish to consider that there is a sharp line of division between molecules and organisms and that viruses belong wholly in one or the other of these two groups. Others may wish to retain the sharp line of division but place some viruses in one group and other viruses in the second

group. However, to a chemist it appears preferable to consider that virus activity may be a property of molecules, that there may be no sharp line of division between molecules and organisms, and that the viruses may provide the transition between the two. One virus has been inactivated and reactivated, and some idea gained of the accompanying change in structure. Studies on the elementary composition, the amino acid distribution, the amount and kind of nucleic acid, the immunological reactions, the effect of different enzymes, the pH and thermal stability ranges, and the effect of many different kinds of chemicals have been completed on some of the viruses. Extensive studies of the physical properties have also been made and the existence of long range forces between molecules has been demonstrated. There is every reason to believe that the extension of these studies will eventually result in the solution of the more fundamental problems related to the viruses, such as the nature of their origin, reproduction and mutation.

THE CONTRIBUTIONS OF TECHNOLOGY

SCIENTISTS, engineers and inventors have created the so-called technological age. We believe that our work and its results are predominantly beneficial to mankind. Some timid souls are frightened at the pace with which technological achievements have come; some see our creations being put to destructive use in warfare and feel that man should not be allowed to have such powerful tools; still others worry about the unemployment that frequently results from introduction of labor-saving machinery or from replacement of one product by a superior one. We technologists, while admitting both accidental and premeditated harmful effects of science, nevertheless see the gains from technology as far outweighing the losses, and we have sure faith in the social value of our efforts.

We see such advances as improved homes, better wages, shorter hours of work, far less disease and suffering, free time for education during youth and for vacations during working years, and, finally, pensions in our old age. None of these happy situations ever existed in the history of the world for the masses of any

people until science and its applications made them possible. Just for one illustration consider this tremendous fact: It has been estimated that during the past three hundred years the population of the earth has increased three times as much as in all the preceding hundreds of thousands of years of man's life on this earth. Knowledge of medicine, disease and health; more fruitful methods of agriculture; methods of fast communication and transportation have combined with other technological factors to push back the starvation, epidemics, infant mortality, floods and other hazards which were continually limiting the earth's population. Whether we like the fact or not, about 1,500,000,000 people are alive to-day who would be dead or unborn except for modern technological progress. Since that figure includes two or three out of every four persons among us, I imagine that if we were to vote on the subject, most of us would be in favor of keeping and further extending the technological progress that has made these things possible.—*Karl T. Compton, Technology Review, June, 1941.*

GEOLOGICAL ASPECTS OF OUR NATIONAL PARKS

II. PARKS ALONG THE CONTINENTAL DIVIDE AND EASTWARD

By Dr. **RAYMOND E. JANSSEN**

EVANSTON, ILLINOIS

NATIONAL PARKS OF THE ROCKIES

THE great inland chain of the Rocky Mountains, carrying the continental divide along its crest, extends from the interior of Canada to New Mexico. Along its length have been established several national parks, both in the United States and in Canada. The present Rocky Mountains are the end products of a series of mountain-making movements which have affected the belt since the Paleozoic Era. The so-called "Ancestral Rockies" were elevated during the Paleozoic, and then brought low by erosion. A reelevation of the chain occurred during the late Mesozoic Era, and subsequent uplifts again took place during the Tertiary Period. The building of the Rockies was accompanied by great volcanic activity, with extensive lava flows and thick deposits of tuff and ashes being erupted in many places.

Foremost among our national parks is Yellowstone, first and largest in our park system. Established in 1872, Yellowstone has since been increased in area from time to time until it now contains 3,471 square miles of territory. The central portion of the park is a broad, volcanic plateau about 8,000 feet above sea-level. Round about are mountain ranges rising from 2,000 to 4,000 feet higher.

The volcanic outpourings which accompanied and followed the rise of the Rocky Mountains continued until comparatively recent times. They gave the park its broad outlines of form in which

it is seen to-day, except in so far as these have been modified by subsequent erosion and denudation. Most of the older granitic and sedimentary rocks were buried beneath lava and volcanic ashes. These lavas issued from several craters in the Absaroka and Gallatin Ranges, as well as from Mount Washburn and Mount Sheridan in the interior of the park. The later flows, mostly of rhyolite, spread widely over the region, forming the park plateau. The rocks have a variety of textures, ranging from soft friable material which easily grinds to powder to the glassy structure of Obsidian Cliff. The very latest eruptions, however, were of basalt. These were small in extent as compared to the other rocks, but quite important from a scenic viewpoint.

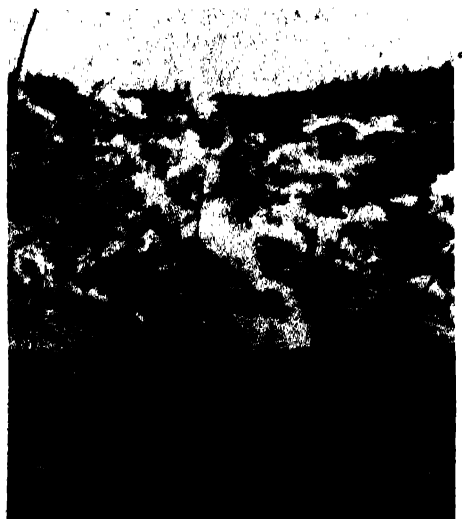
Presumably, the park was almost entirely covered by a vast ice sheet during the Ice Age, for evidence of its work may be seen throughout the region. The huge granite boulder perched near the Canyon of the Yellowstone must have been brought there by ice, since its counterpart is not known within twenty miles. By plowing out valleys and lake basins, and rounding and smoothing elevations, ice has surpassed any other agent in giving the park its present topography.

The thermal activity in Yellowstone Park, for which it is most famously known, presumably dates from the last of the volcanic eruptions. It is known to antedate the glacial epoch, since glacial drift occurs on the top of Terrace Moun-



Photo by author

HARD BASALTIC LAYER
OVERLYING THE DECOMPOSED RHYOLITES OF THE
YELLOWSTONE PLATEAU, AND STANDING OUT IN
MANY PLACES AS A SHEER WALL.



Courtesy Chicago & North Western Railway
CHANGES IN SUBSURFACE STRUCTURE
IN YELLOWSTONE PARK ARE CONSTANTLY TAKING
PLACE, WITH RESULTING CHANGES IN THERMAL
ACTIVITY AT THE SURFACE. INCREASED ACTIVITY
AT ROARING MOUNTAIN HAS RECENTLY DESTROYED
PART OF THE FOREST.

tain, which is a hot springs formation. The present hot springs and geyser areas represent only a very small part of the former wide-spread thermal activity experienced by the region. Decomposition of volcanic rocks, caused by the action of steam and hot water, may be seen throughout the plateau. The beautiful coloring of Yellowstone Canyon is the result of such decomposition. Other areas of similar decomposition are evident in recent road cuts.

The thermal springs, which consist of both the eruptive geysers and non-eruptive hot springs, number about 3,000. Most of them are situated in the six principal geyser basins lying in the west and south central parts of the park.

Geysers are defined as periodically eruptive hot springs. They can occur only where high interior temperatures approach closely to the earth's surface. They must also possess a tube or "plumbing system" which is crooked or constricted in such a way as to prevent easy circulation of the water. The walls and cracks of this system must be made of silica or other rock which is strong enough to withstand the pressure and explosive action of steam. In operation, heat causes the water in the lower portion of the tube to expand to the extent that the cooler water above can no longer hold it down. The water then begins to bubble over, relieving the pressure of the superheated water below. The release of pressure immediately allows the superheated water to flash into steam, thereby causing the eruption. After the tube again fills with water, the process is repeated.

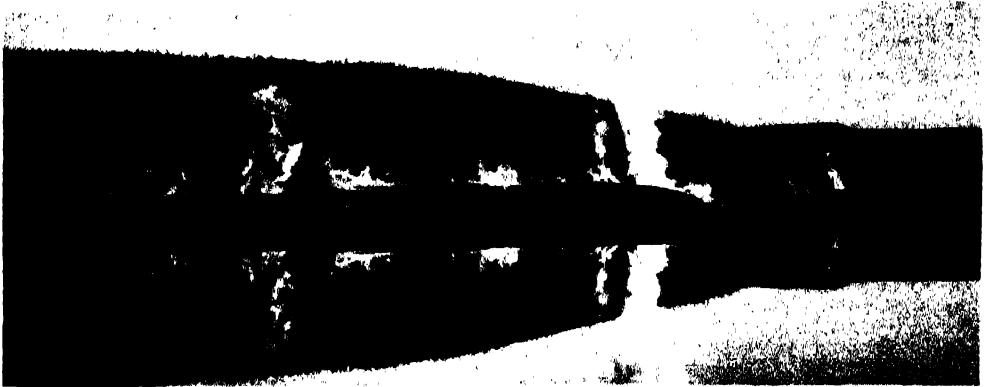
Since the subsurface system of each geyser differs somewhat, there is wide variation in their activity, dependent largely upon the length of time required for their respective tubes to refill and the water to become heated. In the case of Old Faithful, the refilling is quite constant so that eruptions are repeated at quite regular intervals. In other cases,

refilling may be much less constant because of factors involving rainfall and general subsurface seepage so that the eruptive periods may be separated by days, weeks, or months. Many of the bubbling hot springs which throw water a few feet into the air every few minutes are really tiny geysers.

Changes in the subsurface structure of the thermal areas are always taking place. Consequently, some geysers and hot springs which have been in existence for a long time may suddenly cease to function. On the other hand, new ones may appear just as suddenly. Mammoth Hot Springs, one of the outstanding fea-

tion of the continental divide. At present the waters of Yellowstone Lake overflow northwardly through Yellowstone Canyon, eventually reaching the Missouri River in northeastern Montana.

Originally, the level of Yellowstone Lake was 160 feet higher than at present. At that time its waters drained southwestwardly into the Snake River, which crosses the southern part of the park, eventually reaching the Columbia River and the Pacific Ocean. There was then no Yellowstone Canyon or Falls, their location being covered by a northward extension of the then larger lake. Just north of the lake, a low divide carried



Courtesy Northern Pacific Railway

GEYSER BASINS OF YELLOWSTONE PARK SHOW EVIDENCE OF HOT ROCKS CLOSELY BENEATH THE SURFACE. THESE INDICATE DYING VOLCANIC ACTIVITY. MANY OF THE GEYSERS AND STEAM VENTS ARE SITUATED IN CLOSE PROXIMITY TO COLD SURFACE WATERS.

tures of the park since its discovery, has been drying up during recent years. At Roaring Mountain, however, thermal activity has been increasing to the extent that wooded areas in the vicinity have had the trees killed by the heat and overflowing water.

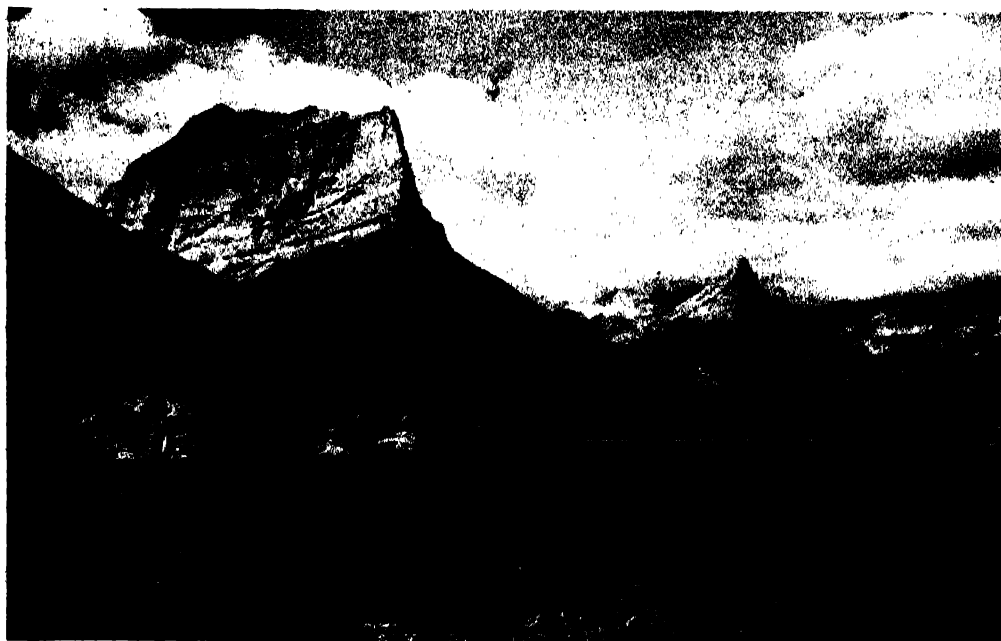
Although the thermal activity of Yellowstone Park fires the imagination, and spreads its fame around the world, much of the geological romance of the park really centers in Yellowstone Lake. Although once flowing into the Pacific, the lake waters now enter the Atlantic, thereby having caused a shift in the loca-

tion of the continental divide. A small stream, called Sulphur Creek, working headwardly toward the top of this divide, eventually tapped the waters of the lake, thereby establishing a new outlet. The main channel of this stream then became the lower Yellowstone River, and subsequent deepening by the river carved Yellowstone Canyon. The Upper and Lower Falls within the canyon are caused by two hard rock dikes which cut across the softer, decomposed rocks of the plateau. As a result of this diversion of the Yellowstone Lake waters through the canyon, and the consequent lowering of the



Courtesy Great Northern Railway

FOLDED AND CRUMPLED ROCKS IN GLACIER NATIONAL PARK
 BEARING EVIDENCE OF THE MIGHTY PRESSURES WHICH CONTORTED THE ANCIENT STRATA. AT THE
 LEFT, WITH ITS CONCENTRIC CREEP MARKS, MAY BE SEEN THE LOWER TERMINUS OF A GLACIER.



Courtesy U. S. Department of the Interior

MANY GLACIER REGION OF GLACIER NATIONAL PARK
 UPPER SAINT MARY'S LAKE, SHOWING CITADEL AND FUSILADE MOUNTAINS. THE EFFECTS OF
 GLACIATION UPON TOPOGRAPHY ARE VIVIDLY SEEN. NOTE THE U-SHAPE OF THE VALLEY.

lake level, the former southern outlet ceased to function, thereby causing the continental divide to shift to the opposite side of the lake.

Just south of Yellowstone Park, extending along the western border of Wyoming, rises the jagged Teton Range. Grand Teton National Park, established in 1929, contains an area of 150 square miles.

The Grand Tetons, which are among the most rugged mountains of America, are an impressive example of block-faulting. The range has its origin in the

later periods. These are topped by young beds of lava which are continuous with those of eastern Idaho and the Yellowstone Park plateau.

The isolated peaks, the knife-like ridges, the precipitous canyons and the polished rock floors which characterize the range are largely the results of glaciation of the Ice Age. A few of the glaciers still remain near the summits, but others have vanished. They have left in their places beautiful cirques and picturesque alpine lakes. As the former glaciers reached the valley floor, they



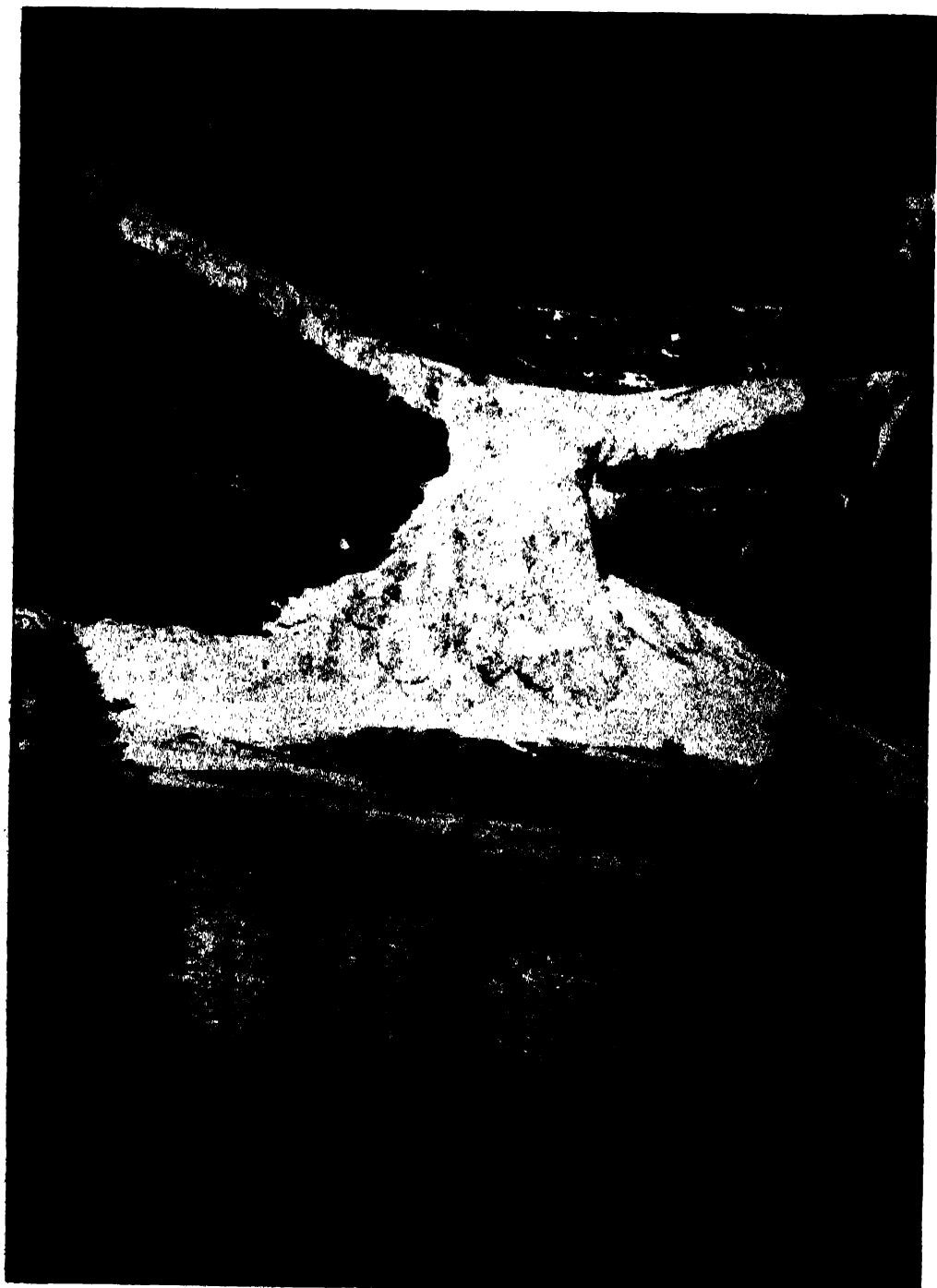
Courtesy U. S. Department of the Interior

THE GRAND TETON RANGE PRESENTS A RUGGED FRONT TO THE EASTWARD
IT IS CUT INTO MANY JAGGED SEGMENTS BY FORMER GLACIERS. NUMEROUS MORAINES ENCLOSE THE
CHAIN OF MANY LAKES WHICH LIE AT THE FOOT OF THE MOUNTAINS.

Rocky Mountain uplift which began at the close of the Mesozoic Era and continued into the Tertiary Period. The eastern face of the range is an enormous fault scarp along which a great block, forty miles long, was uplifted and tilted westwardly. The total amount of uplift along the eastern side of this block approximated 10,000 feet, or more. Viewed from the east, one sees the precipitous side of this block, made up largely of very ancient, uplifted pre-Cambrian crystalline rocks. On the west flank are overlying stratified rocks of

dropped their loads of rock material in morainic dams behind which were impounded the waters of Jenny Lake, Taggart Lake, Jackson Lake and others which line the valley along the Teton front. The wide valley floor, known as Jackson Hole, is an outwash plain, strewn with the gravels which were deposited there by the streams of melting ice water.

The effects of glaciation, as well as mountain faulting, are exemplified to much greater degrees in Glacier National Park. Glacier Park, occupying 1,538



Courtesy Chicago & North Western Railway

LIKE A FROZEN WATERFALL, A GLACIER POURS ITS ICE OVER A CLIFF
REFORMING AS A "RECONSTRUCTED GLACIER" BELOW.

square miles of our northern Rockies, represents the American section of Waterton-Glacier International Peace Park, established by joint action of Congress and the Canadian Parliament in 1932.

The Rocky Mountain Front in this region, like that of the Tetons, consists of an enormous fault extending for many degrees of latitude across Montana and Alberta. The faulting here, however, not only elevated the rocks vertically, but also thrust them eastward horizontally so that they overlapped strata of much younger age. This overthrust faulting was of such proportions that it carried deep-seated rocks of Proterozoic age up and over on top of Cretaceous rocks for a horizontal displacement of at least fifteen miles, making this one of the greatest overthrusts known. This action occurred during the Rocky Mountain uplift; hence it involved not only the very ancient Proterozoic rocks, but also all the overlying Paleozoic and Mesozoic strata of the region. Subsequent erosion has removed most of these overlying strata along the eastern front, however, thereby exposing the Proterozoic rocks resting on top of Cretaceous rocks which are some 500,000,000 years younger. Chief Mountain, on the eastern border of Glacier Park, is a detached block of overthrust Proterozoic rock lying on top of the Cretaceous plain. Similar relationships of the rocks may be seen in Swiftcurrent, St. Mary and Cutbank valleys.

The massive continental glacier, moving down from the North, overrode the uplifted mountains of Glacier Park, carving them to an extent not paralleled in any of our other national parks. As a consequence, there now are precipitous cliffs four and five thousand feet high, enormous U-shaped valleys once the channels of glaciers, knife-like edges on high divides, hundreds of cirques and glacial lakes and thousands of tiny

streamlets trickling down from the sixty glaciers which still remain as remnants of a once more extensive ice cover. Individually, the glaciers of Mount Rainier surpass those of Glacier Park, but the phenomena of former glaciation in all its multiplicity is best revealed in the intricate sculpturing of the Rockies in Glacier National Park.



Courtesy Great Northern Railway
MELTED GLACIER

GLACIER SIMILAR TO THAT ON OPPOSITE PAGE HAS LONG SINCE MELTED AWAY, LEAVING TWO LAKES, ONE ABOVE AND ONE BELOW THE PRECIPITOUS CLIFF.

The Rocky Mountain System, which comprises many ranges, reaches its climax of altitude in Colorado. The state contains 765 peaks which attain an altitude of more than 11,000 feet. Of these, 45 exceed 14,000 feet in height. Mount Elbert, 14,420 feet in altitude, is exceeded in height within the United States only by Mount Whitney in Cali-



Courtesy Chicago, Burlington & Quincy Railroad

**MASSIVE SUMMITS OF COLORADO ROCKIES RISE IN CRAGGY RELIEF
THROUGHOUT ROCKY MOUNTAIN NATIONAL PARK, EXTENDING ENDLESSLY ACROSS THE HORIZON.
NOTE THE BOWL-SHAPED CIRQUES AND U-SHAPED VALES WHICH INDICATE FORMER GLACIERS.**

fornia, which is merely 75 feet higher. About one seventh of Colorado exceeds 10,000 feet in altitude.

In such a setting as this has been established Rocky Mountain National Park, occupying a portion of the Front, or Snowy, Range of the southern Rockies. Containing 405 square miles of area, the park itself represents only a small portion of this extensive mountain system. Of the four national parks situated in the Rocky Mountain Chain, only this one exhibits in marked degree the true characteristics of the chain's internal structure. The rocks here are prevalently granite, upwelled during the Rocky Mountain revolution, subsequently uncovered by erosion in a fashion comparable to the granitic scenery of the Pacific Chain. Dominated by Long's Peak (14,255 feet high) the Front Range presents a long, majestic face to the east where it overlooks the broad expanse of

the Great Plains. Originally, Long's Peak and the adjacent peaks, which are nearly as high, were a single mountain. Erosion and glaciation have cut deep valleys, baring the granite core and slicing the range into distinct segments. The east side of Long's Peak is a sheer precipice of 1,200 feet, beneath which is glacial Chasm Lake, held in place by a morainic dam. Although the legible record of Ice Age glaciation here is most distinct, it does not equal the vivid records so profoundly displayed in Glacier Park. For sheer mountain massiveness with its endless array of peaks in range after range, Rocky Mountain Park, however, exhibits the finest example of the continental mountain structure in our national park system.

MOUNTAIN PARKS OF THE EAST

Far older in age than any of our western mountains are those which lie east

of the Mississippi. Here several national parks have been established. Three of these, Acadia, Shenandoah and Great Smoky Mountains national parks, are situated in the Appalachian belt.

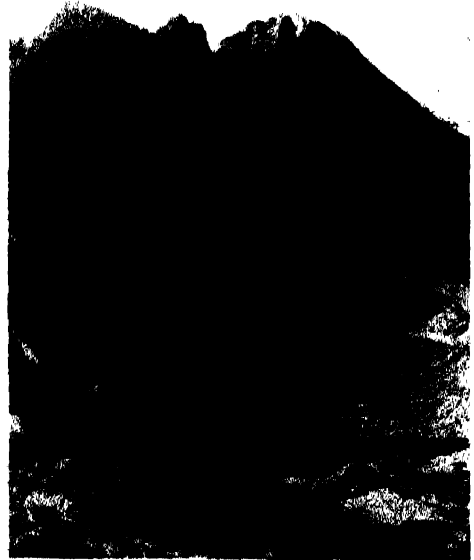
The Appalachian Mountains themselves were preceded in point of time by another series of ranges, called the Acadian Mountain System, which extended through the maritime provinces of Canada, New England and along the coastal region as far south as Virginia. The building of the Acadian Mountains occurred at the close of the Devonian Period, following which they were worn low by erosion. At a much later time, recurring earth movements along this belt at the close of the Paleozoic Era gave birth to the Appalachians. Extending from Newfoundland to Alabama, the Appalachian Mountains were then comparable in height and grandeur to the present ones of the West. They were worn low during the succeeding Mesozoic Era to a more or less level peneplain in which the hard and soft rocks of the folded mountains were beveled off alike. At the close of the Mesozoic, this low peneplain was reelevated to new heights.

Ever since that time, erosion has continued to dissect this uplifted belt, culminating in the present configuration of the ancient structures. Where less resistant rocks were at the surface, valleys came into prominence; where harder rocks formed the surface, the old peneplain level is still preserved. As one stands upon the crest of these eroded mountains and looks out across the panorama of hills and vales, he can not fail to be impressed with the common level of all the higher elevations. The old peneplain is there, etched against the horizon and dissected only by the valleys which have been worn in the ancient rocks.

It is for these far-reaching views across the old peneplain that Shenandoah and Great Smoky Mountains parks are noted.

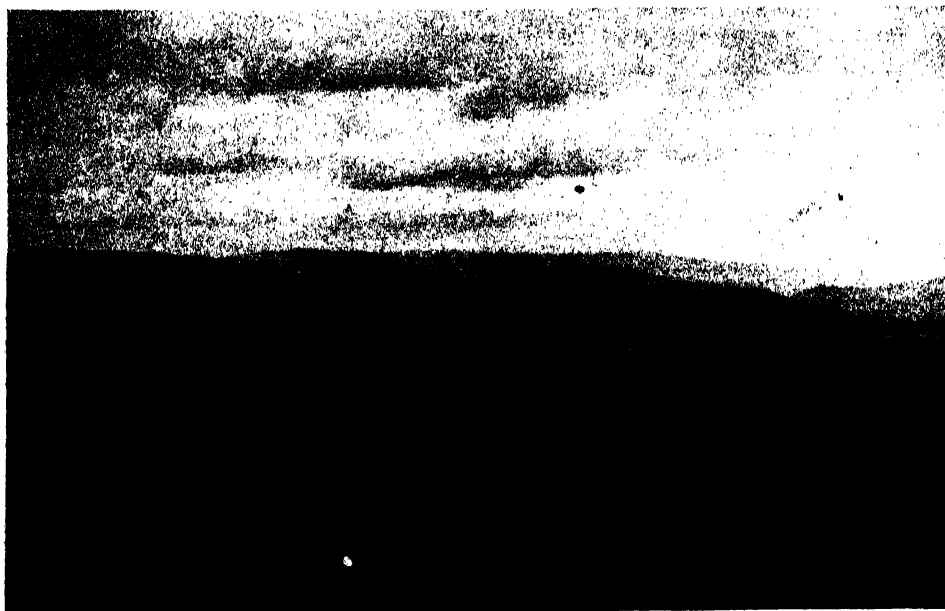
An appreciation of this geologic history may be obtained by traveling along Sky-line Drive, which extends for a distance of nearly 100 miles along the crest of the Blue Ridge Mountains in Shenandoah National Park. Along this parkway, one may search in vain for signs of glaciation. No U-shaped valleys, no moraines, no cirques nor glacial lakes exist. It is stream erosion alone which has shaped these ancient mountains.

Glaciation, however, has produced the configuration of our easternmost national park—Acadia—located on Mount Desert Island off the coast of Maine. The island is deeply indented by numerous bays and inlets, one of which nearly cuts the island in half. This inlet, called Somes Sound, is a fiord or glacial estuary, the only one along our Atlantic coast south of Newfoundland. It had its origin as a glaciated valley during the Ice Age. Sinking of the shoreline following the gouging of the valley produced the fiord. It



Courtesy Chicago, Burlington & Quincy R.R.

EASTERN SIDE OF LONG'S PEAK
SOURCE OF A GLACIER WHICH FLUCKED AWAY THE
MASSIVE GRANITE CORN OF THE MOUNTAIN, FORM-
ING A SHEER PRECIPICE OF 1,200 FEET.

*Photo by author*

THE NEARLY LEVEL SUMMITS OF THE APPALACHIAN MOUNTAINS
THESE LEVEL SUMMITS MARK THE SURFACE OF AN ANCIENT PLAIN WHICH HAS BEEN UPLIFTED AND
SINCE DISSECTED BY STREAM EROSION.

is comparable in origin to those along the coast of Norway.

Except for the effects of glaciation and the subsidence of the region, the geological history of Acadia National Park is associated with the Acadian and Appalachian uplifts. Here the mountains are believed to have once reached elevations of at least 15,000 feet; but if so, they have since been worn so low that only the ancient granitic core now remains. Along this rock-bound coast of Maine, we may view a geologic epic wherein the sea emerges triumphant in its age-long conflict against the land.

Having no connection whatever with the Appalachian Mountain System is Isle Royale National Park in Lake Superior, established in 1940. Although quite young as a national park, it is most ancient in origin. With a land area of more than 200 square miles, Isle Royale Park consists of one large island and an archipelago of many smaller islets. Ris-

ing only slightly above the waters of Lake Superior, the land surface of Isle Royale can not now be considered as mountainous, although it might well have been so in the past.

The rocks forming Isle Royale are of Proterozoic age, and hence are comparable in time of origin with the lowermost strata which rest on the ancient granites at the bottom of the Grand Canyon. That volcanic activity was most pronounced at this time in the Lake Superior region is evidenced by the many lava flows which have here been piled successively upon each other. What happened to these lava rocks of Isle Royale during the half billion years or more of elapsed time since their formation until the coming of the ice sheets is largely a lost chapter in their geologic history. All evidence was swept away when the ice completely overrode the Great Lakes region. The topography of Isle Royale, as we see it to-day, is essen-

tially the same as it was left after the recession of the last ice sheet.

THE SUBTERRANEAN PARKS

The profound effects of running water may not only be appreciated in the mighty canyons which cut the surface of our lands, but also in the extensive subterranean caverns which have been hollowed out within the rock formations below the surface. Simply stated, cav-

drainage of the region either by flowing out of the caverns or by underground passages. Many large springs are nothing more than underground streams which have passed through caverns and emerged upon the surface.

The material dissolved by the underground waters is eventually carried to the surface rivers and thence out to sea, or else deposited again en route. When this ground water becomes saturated



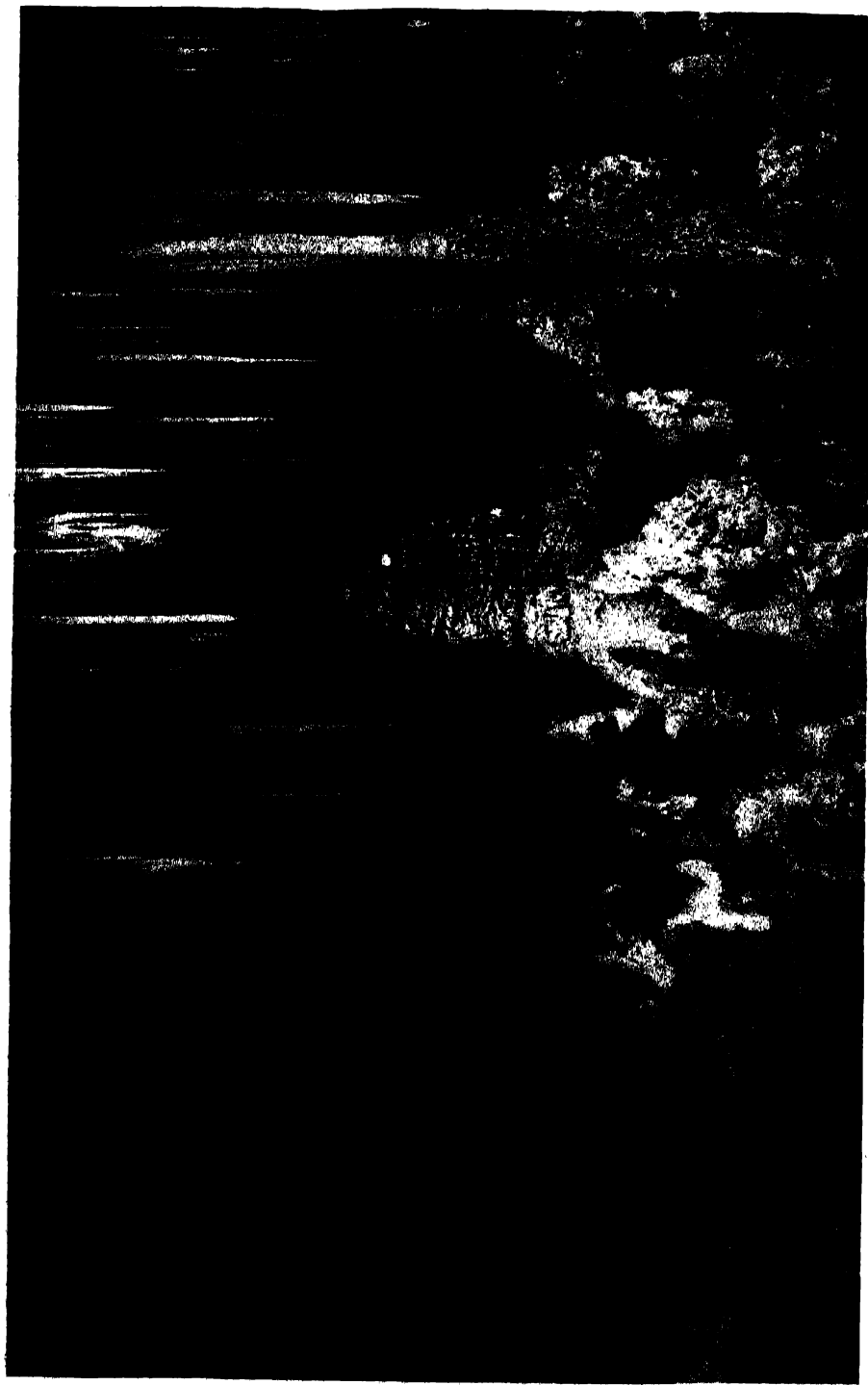
Courtesy U. S. Department of the Interior

THE ROCKBOUND COAST OF ACADIA NATIONAL PARK

FORMED BY THE SUBSIDENCE OF AN OLD ERODED LAND SURFACE WHICH TURNED MANY OF ITS LOWER STREAM COURSES INTO BAYS, ESTUARIES AND SMALL ARMS OF THE SEA.

erns are joints or cracks which have been greatly enlarged by the solution action of the ground water passing through them. Large caverns are developed only in soluble rocks, principally in limestones, dolomites and gypsum, and sometimes in salt. Water moving through such strata makes its way along the joints, gradually enlarging them by solution and usually collecting in underground streams. These streams, some of which are quite large, join the surface

with mineral matter, slight changes may cause deposition of some of the material. One of the most common causes is the loss of carbon dioxide from the water. When highly charged water slowly drips from the roof of a cavern, loss of carbon dioxide occurs, and some of the dissolved mineral matter may then be precipitated. This gives rise to beautiful cave formations such as stalactites, stalagmites, pillars and onyx draperies. Thus the process of dissolution may give way to



Courtesy Santa Fe Railway

MAGNIFICENT CAVE FORMATIONS IN CARLSBAD CAVERNS

BUILT BY DRIPPING WATERS, CHARGED WITH CALCIUM CARBONATE. STALACTITES, LIKE ICICLES, GROW DOWNWARD FROM THE CEILINGS. DROPS OF WATER WHICH SPLASH UPON THE FLOORS BUILD UP CONE-LIKE STALAGMITES. SOMETIMES A STALACTITE AND STALAGMITE WILL JOIN TO FORM A PILLAR, AND CONTINUED TRICKLING OF WATER DOWN ITS SIDE MAY INCREASE ITS BULK AND VARY ITS CONFIGURATION.

that of deposition in the previously hollowed caverns.

Three large underground caverns—Wind Cave in the Black Hills region of South Dakota, Mammoth Cave in Kentucky and Carlsbad Caverns in New Mexico—have been incorporated into our national park system. Wind Cave received its name by virtue of its discovery through a strange whistling sound caused by air escaping from a small hole in the ground. This current of air, which alternately moves in and out of the cavern, is apparently caused by differences in atmospheric pressure outside. When the barometer is falling, the current moves outward; when the barometer rises, the current blows inward. This hole, only ten inches in diameter, is the only known natural surface opening to the cavern.

The interior of the cavern, reached by a specially constructed entrance and elevator, is noted for its crystal formations known as frostwork and boxwork. The frostwork consists of tiny white crystals on a tan or pink background and hang like frost upon the ceilings and ledges. The boxwork consists of fin-like projections of calcite which hang from the ceiling in a sort of honeycomb pattern. This boxwork is a depositional feature peculiar to Wind Cave.

The famous Mammoth Cave of Kentucky has been set aside for protection by the National Park Service, but will not obtain full park status until some 45,000 acres have been deeded to the government. At present, nearly 43,000 acres have been acquired. Mammoth Cave has become so well known since its discovery in 1799 that it requires little description. Its many ramifications, of which nearly 200 miles of avenues have been explored, are only part of an extensive network of subterranean passages which have been formed in the Lower Carboniferous limestones of the Mississippi Valley.

These limestones were laid down at the bottom of a sea which then covered a vast part of the North American continent, extending from the Arctic to the Gulf of Mexico. Eventually the region was elevated above the sea, and since the close of the Paleozoic Era the Mammoth Cave area is believed to have remained dry land. Consequently, there has been



Courtesy Santa Fe Railway

ENTRANCE TO CARLSBAD CAVERNS

IN THE SEMI-DESERT FOOTHILLS OF THE GUADALUPE MOUNTAINS IS AN UNPRETENTIOUS OPENING WHICH LEADS TO THE MOST EXPANSIVE UNDERGROUND WONDERLAND OF THE EXPLORED WORLD. BATS, MOVING IN AND OUT OF THIS OPENING, ATTRACTED ATTENTION WHICH LED TO THE DISCOVERY OF CARLSBAD CAVERNS.

adequate time for the percolating ground waters to dissolve out the massive caverns during the more than 200,000,000 years which have since elapsed.

Of unusual magnificence and extent are the underground passages constituting Carlsbad Caverns National Park in the foothills of the Guadalupe Mountains of New Mexico. The Guadalupe Mountains are outliers of the Rockies farther north. The limestone in which the cav-

erns have been formed is slightly younger in age than that of Mammoth Cave, having been laid down during the Permian Period, immediately following the Carboniferous. The earth movements which raised the Rocky Mountains also raised the Carlsbad area—some 60,000,000 years ago. Since then, underground waters have hollowed out the enormous caverns and refilled them partially with the beautiful formations which are unique to underground passages.

Although recognized as the greatest underground labyrinth yet discovered, the extent to which the caverns may penetrate beneath the Guadalupe Mountains is not yet known. Since the discovery of the caverns in 1901, three general levels of passageways have been located. The first of these is 750 feet below the surface, and is the level to which visitors are conducted by elevator. Below this is another vast level at 900 feet, and a third at 1,320 feet. None of these has been completely explored, and additional levels may also exist.

About seven miles of passageways have been developed and opened to visitors. The largest of the passageways, called the Big Room, is about 4,000 feet long, 625 feet wide, and at the highest point the ceiling arches 350 feet above the floor. Such an excavation indicates an enormous power of dissolution and removal by underground waters. Within this room, the formations which were later deposited are massive as well as magnificent. In size, the stalactites, stalagmites and fluted columns vary from pencil-like structures to those approximating the dimensions of giant trees. Here human comprehension seems to become lost in a maze of fantasy, for one finds it difficult to believe that so vast and magnificent a spectacle could have been formed merely through the agency of little trickles of water. Carlsbad is to the subterranean world what the Grand Canyon is to the surface.

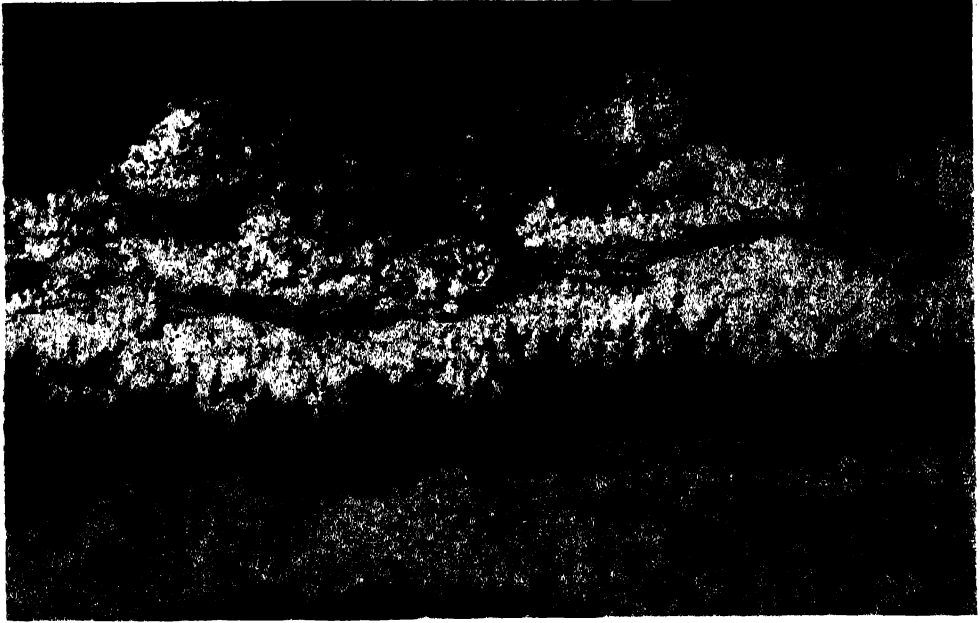
THE MINERAL SPRINGS PARKS

Two minor national parks deserve consideration because they contain mineral springs of therapeutic value. These are Hot Springs National Park, in the southern Ozark Mountains of Arkansas, and Platt National Park, in the Arbuckle Mountain region of southern Oklahoma.

Hot Springs became a national park in 1921, but it had been set aside as a government reservation as early as 1832. In a sense, this 1½ mile area might be considered as our first national park, although Yellowstone was really first established and administered as such. The springs themselves, of which there are 47, were famous for their therapeutic value before the white man discovered them. There is some indication that they gave rise to the rumor which brought Ponce de Leon from Spain in search of the Fountain of Youth. Indian tradition maintains that the springs were always considered as neutral territory by the warring tribes. The waters of the several thermal springs, which are practically identical in chemical composition, are now impounded in reservoirs, and all bath-houses receive the same water. Temperature of the water is always over 140° F.

Platt National Park, with an area of only 1½ square miles, and established in 1906, contains 32 springs of major importance. Of these, 18 are classified as sulfur, 6 as fresh water, 4 as iron and 3 as bromide. The latter are the only known natural bromide springs.

The rocks exposed in both parks are composed of sediments laid down beneath a former sea during early and middle Paleozoic times. Later, during the Great Coal Age, this region was folded and buckled into mountain ridges, with numerous faults, or breaks, permitting slippage along the lines of greatest strain. The mountains thus formed were later nearly leveled by erosion, but



Courtesy Chicago, Burlington & Quincy Railroad
FROSTWORK FORMATIONS OF PURE WHITE CALCITE
 ADORN THE CEILINGS AND LEDGES OF WIND CAVE.

subsequent uplifts during the Appalachian and Rocky Mountain revolutions also elevated this region to new heights. Subsequent erosion has finally produced the present topography. The springs issue from fractures in the rocks, primarily along the old fault lines.

Several theories have been advanced as to the mechanism of the thermal springs. Most generally accepted is the meteoric theory which suggests that rain-water seeps downward along the slope of the formations and becomes confined between impervious layers. Eventually it finds outlet along the fractures or faults in the strata. Somewhere along its underground path it becomes heated by passing near a mass of un-cooled rock. Another theory suggests that the water from the hot springs does not originate from rain seepage, but comes solely from the earth's interior. Such water, called juvenile water, escapes from molten rock as it cools, and thence finds its way to the surface. Other theories presume that chemical

reactions or radioactivity in the rocks causes the heat which warms the waters. Regardless of the source of the heat and the water, the flow at Hot Springs National Park remains almost constantly at 1,000,000 gallons daily.

OUR NATIONAL PARK SYSTEM

The original motive in establishing national parks was that of conservation. The reservation of Hot Springs in 1832, and of Yellowstone in 1872, was for the prime purpose of protecting these areas from exploitation. That purpose still remains, but with the passing of the years, perspectives have broadened. The park system now also aims to portray by striking examples the great truths of natural science and the progress of civilization upon the continent.

The National Park Service was created in 1916, when it assumed supervision of the 16 national parks and 21 national monuments then under the control of the Department of the Interior. Our national park system really had its



Courtesy Chicago, Burlington & Quincy Railroad

A PECULIAR BOXWORK FORMATION OF CALCITE

FOUND ONLY IN WIND CAVE, WHICH ASSUMES A HONEYCOMB ASPECT UPON THE CEILINGS.

birth around a campfire, the site of which is still preserved in Yellowstone. The Washburn-Langford-Doane Expedition in 1869, the first scientific expedition to investigate the Yellowstone region, advanced the idea which led to the establishment of the first national park.

To-day our national parks are scattered through nineteen states and two territories. They extend from Maine to Hawaii, and from Alaska to Mexico. These parks occupy more than 10,320,000 acres of land. If the area of the national monuments and historical parks is added, the total acreage is more than doubled. More than 16,740,000 persons visited our national parks and monuments in 1940, the 26 national parks here considered attracting nearly half of these. That interest in our national reservations is increasing steadily is indicated by the fact that the total attendance for all units during 1933 was less than 3,500,000 persons. The most popu-

lar national park is Shenandoah, which registered nearly a million visitors last year.

Although our national parks include regions of the most diversified scenic grandeur of the world, they also contain many of the most complete records of the earth's long and eventful history. From the ancient granites at the bottom of the Grand Canyon to the glistening glaciers on the peak of Mount McKinley, is recorded in startling clarity the age-long story of an ever-changing world. Here, too, we may see in action the mighty geologic processes which have fashioned our lands.

Our great natural wonders are not, in any sense, completed. They are still in process of formation and evolution. Some day the last of Yellowstone's geysers will cease to erupt, and the last lofty glacier may melt away; but no person now living will witness these events. And again, new landscapes and new wonders will come into being.

RELATIVES AND HUMAN GENETIC ANALYSIS

By Dr. C. W. COTTERMAN

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IN laboratories and clinics where research work is being conducted in human biology and medicine an increased interest is being shown in the study of relatives. As soon as this happens the research can, of course, be described as genetical. Now close relatives can often be secured with little extra effort, whereas the compilation of extensive family histories—the traditional approach—may be quite beyond the facilities of the research. This suggests that an even greater interest in human heredity might be manifested were the following facts more widely known.

Genetics could be defined as the study of the consequences of biological relationship, and we might therefore expect that *any* kind of relationship would provide *some* information about inheritance. Equally, we should expect that the closest relatives would be by far the most useful to the geneticist. Logical though these statements might appear, their full significance may not always be appreciated. For it is not uncommon to hear the view expressed that in order to offset the lack of experimental opportunities it is necessary in the study of human genetics to obtain very long and extensive pedigrees. Such pedigrees are indeed often very instructive, but for most genetical purposes they are certainly not essential and, in fact, may be considerably less useful than smaller units. In any event, the clinical investigator need not be daunted should he find it inconvenient or impossible to examine distant relatives.

The human geneticist is now provided with a variety of statistical procedures which have been specially devised for the

peculiar conditions under which human heredity must be studied. These methods are designed to make use of data which appear very fragmentary and heterogeneous in contrast to the data of the experimental geneticist. Many of the techniques require only single families or even parts of families—pairs of brother and sister or parent and child. Some of the mathematical possibilities in this direction are indeed rather surprising. But at the present time, and probably for some time to come, most genetical data on man will be assembled by medical and other workers who are not directly concerned with its genetic analysis. Consequently there is some fear that many kinds of observations may be discarded unless it is realized that the appropriate analytical methods are available.

The mere realization of these opportunities, however, is not quite sufficient, for unless certain precautions are taken in recording the information the data will frequently be very misleading and therefore worse than useless. Practical suggestions for the clinical worker who wishes to safeguard his observations from this fate have been made available in excellent form by Roberts,¹ Macklin² and others. No special effort will be made here to call attention to these points; nor will the article deal with the aforementioned mathematical methods. It will rather attempt to summarize an intermediate ground—the genetical consequences of various kinds of relationship and the opportunities which they afford for special types of genetic analysis.

¹ J. A. Fraser Roberts, "An Introduction to Medical Genetics." Oxford. 1940.

* Investigations in human heredity at the University of Michigan are supported by The Horace H. Rackham School of Graduate Studies.

² M. T. Macklin, *Sci. Monthly*, 51 (1): 56, 1941.

RELATIVES—KIND AND DEGREE

Genetically considered, there are only two *kinds* of relatives, provided we ignore the possibilities of inbreeding. These two kinds of relationship, which we shall term *unilineal* (A) and *bilineal* (B), are illustrated in Fig. 1, which makes use of the customary arrow diagrams. In each diagram the relatives in question are the two indicated by blackened circles. Each individual is connected to his parents by the two lines

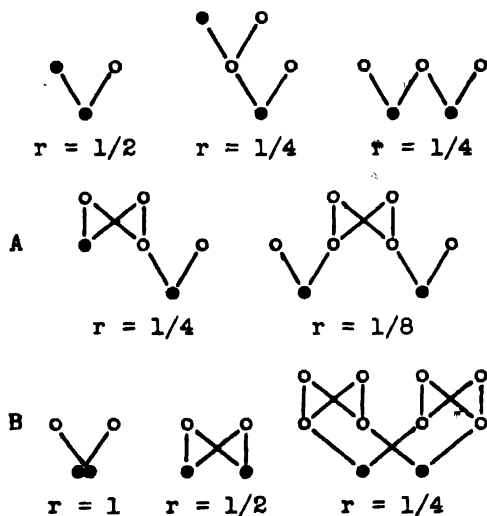


Fig. 1.

which lead upwards. It is then easy to see that the examples of A-relatives depicted are, in order, parent-child, grandparent-child, half sibs,^{2a} uncle-nephew and single first cousins. The B-relatives represent one-egg or "identical" twins, full sibs and double first cousins.

In each example the symbol r denotes the *degree*, or coefficient, of relationship, as devised by Professor Wright.³ Numerically, it can always be found by taking $(\frac{1}{2})$ to the power of the number of links in a path of descent connecting the

^{2a} In genetics "sibs" are children (male or female), of the same parents; "half sibs" are children having only one parent in common.

³ Sewall Wright, *Amer. Naturalist*, 56: 330, 1922.

two relatives and summing such terms for all possible paths. Genetically, r is the probability that, for any (autosomal) gene specified in the one individual, the relative will possess the *same* gene—same in the sense of common origin. It may also be interpreted as the most likely fraction of *all* genes to be shared by the two relatives.

The two kinds of relatives, A and B, are differentiated by the fact that only in the case of B-relatives are there two paths of which all links are separate or independent. This means that it is impossible for A-relatives to share both genes of a pair; but not so for B-relatives. More exactly, if we denote by A_0, A_1, A_2, A_{12} the probabilities that neither, the one, the other, or both genes of a pair will be shared by A-relatives, and similarly for B, we find, for any degree of relationship, r , the following conditions:

$$\begin{array}{ll} A_0 = 1 - 2r & B_0 = (1-r)^2 \\ A_1 = r & B_1 = r(1-r) \\ A_2 = r & B_2 = r(1-r) \\ A_{12} = 0 & B_{12} = r^2 \end{array}$$

Thus, for half sibs, $A_0 = \frac{1}{2}$, $A_1 = A_2 = \frac{1}{4}$, $A_{12} = 0$; for double first cousins, $B_0 = 9/16$, $B_1 = B_2 = 3/16$, $B_{12} = 1/16$; and so on. It will be noted that, in accordance with the definition of r , we always have $A_1 + A_{12} = r$ and $B_1 + B_{12} = r$.

We may now discuss some of the advantages of bilineal relatives. Whatever these advantages might be, we should expect them to arise from the fact that B_{12} , unlike A_{12} , is not zero.

The formation of one-egg twins is, of course, an asexual process, but genetically such twins can be regarded as B-relatives of degree $r = 1$, for we then have the familiar fact that their gene-pairs must be identical throughout: $B_{12} = r^2 = 1$. The advantages afforded by this unique relationship need hardly be dwelt upon here. By possessing pairs of genetically uniform subjects we of course greatly simplify the problem of assessing the relative influence of heredity and

environment. It is interesting to note, however, that having $r=1$ is, in a sense, carrying a good thing too far. For, since there can be no genetic variation at all, "identical" twins can not in themselves afford any information as to the mode of inheritance; their value lies rather in demonstrating the fact of inheritance. But certainly, whatever the nature of the genetic study, the investigator should make full use of multiple births and might well undertake a special search for them. In interpreting the data he must of course first decide which of his pairs are of one-egg and which of two-egg origin. This diagnosis, as well as methods of nature-nurture analysis, is discussed by Dr. Newman⁴ in a recent book in the American Association for the Advancement of Science Series of non-technical books.

Full brothers and sisters are B-relatives of degree $r=\frac{1}{2}$, and we therefore have $B_0=B_1=B_2=B_{12}=\frac{1}{2}$. This explains the facts observed in human pedigrees which involve recessive abnormalities. By definition, a recessive gene is one which is required to be present in double dose in order to produce a detectable change. Let us now consider any defective individual who possesses two such genes. If the gene is quite rare in the population, then we may assume that if any of his relatives are affected at all they will be so by virtue of sharing the same two defective genes. Now $A_{11}=0$, but $B_{11}=r^2$. Hence we do not expect the parents, or children, or in fact any of the A -relatives to be affected, but we always expect one fourth of the brothers and sisters to be affected. Hereditary abnormalities of this sort are therefore sometimes called familial diseases; they are likely to appear in the sibship, especially if it is a large sibship, but will usually be absent in the patient's own ancestors or descendants. In studying traits suspected of being recessive in inheritance the investigator should search for them, not only in the sibship, but also in the

the clinician will, of course, do well to specialize on the sibs of his patients.

Another kind of genetic study which depends largely on the comparison of sibs is the investigation of genetic linkage, the location of two or more gene-sets in the same chromosome. The main statistical effect of this phenomenon is the production of a two-way intrafamilial correlation. That is to say, in some families there is a positive, in others a zero, in still others a negative correlation between the grades of the two characters. The over-all correlation is therefore likely to be zero. These generalizations were first clearly brought to light in the studies of Dr. Penrose,⁵ who developed special statistical tests for the detection of linkage in data consisting of sibships of unspecified parentage. In this connection Professor Fisher⁶ has shown that lack of information about the parents need only entail a loss of 13 per cent. of the precision secured by the examination of children and parents combined. This surprising result furnishes a good illustration of the fact that the study of heredity need not concern itself with the comparison of ancestor and descendant.

Sibs also present certain practical advantages which must not be overlooked. Compared with other sets of relatives they will usually be less variable in age and will probably have been exposed to more nearly similar environments. Moreover, up to a certain age the entire sibship will usually be available as a unit for examination. In certain kinds of studies it may be possible to exercise some selection of cases, and it is then useful to know that the precision or amount of information provided by a sibship is usually an increasing function of its size. In several kinds of analysis it is found that the amount of information furnished by a sibship of n members is proportional to $(n-1)$, this being

⁴ L. S. Newman, *Genetics*, p. 122, 1933, Mac. & Co., New York.

⁵ L. S. Penrose, *ibid.*, p. 122, 1933.

⁶ R. A. Fisher, *ibid.*, p. 122, 1933.

the number of sib-pair comparisons which can be made. Thus, in such studies, single-child families are worthless, a fraternity of 5 gives 10 times the information of a fraternity of 2, and a fraternity of 8 is worth 28 times as much.

As we have just seen, some very valuable information can be obtained from data of even a single generation. Actually, certain genetic phenomena can be investigated without studying any relatives whatsoever. This is well known to the physician who inquires from the patient concerning the possibility of consanguinity in the parents. Fig. 2 shows the offspring of three different consanguineous matings: parent-child, brother-

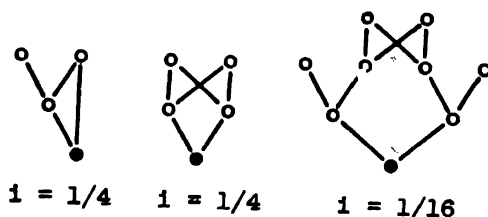


FIG. 2.

sister and single first cousins. In each case i represents the coefficient of inbreeding⁷ of the resulting child. This is simply half the coefficient of relationship, r , of the parents, and gives, for any particular gene-pair, the probability that both genes were derived from a single gene present in one of the ancestors common to both parents. Inbreeding is therefore of significance in connection with recessive inheritance. If the incidence of some rare recessive disease is q^2 , then the probability that an inbred individual of degree i will receive two such genes and therefore show the defect is $i q + (1-i) q^2$. Thus, for a recessive defect appearing in 1 per 10,000 of unrelated persons the expectation is increased 7-fold for offspring of single first cousins and 26-fold for offspring of parent-child incest.

Since this effect will be observed by the clinician the other way round, by

⁷ Sewall Wright, *op. cit.*

merely inquiring about consanguinity in the parents of single patients he may acquire some valuable information on the mode of inheritance. If the disease is caused by recessive factors, the proportion of cases in which subjects report consanguinity will be considerably larger than the proportion of such matings in the general population. Rare dominants, on the other hand, will not be caused to appear in greater frequency through inbreeding.

Penrose⁸ has recently suggested that it might be equally advisable for the medical worker to inquire about consanguineous marriage in the grandparents. Certain anomalies of development suggest that they may be conditioned by the genotype of the mother rather than that of the child. Hence, if the genetic factor were a recessive, the defect would be associated with excess consanguinity in the maternal grandparents. Abnormalities due to certain kinds of chromosome derangement might also be expected to show this effect.

Most of the known pathological genes of man are of the sorts known as dominants, "provisional" dominants and "irregular" dominants. Only a single gene is necessary to produce the defect in some, if not all, individuals. Whether the gene is incompletely dominant, that is, whether it would produce a more severe defect in double dose, is usually unknown since, being rare, the gene is never given the opportunity of occurring in that state. Now since only a single gene is required, we see that the probability of any relative being affected is simply equal to the coefficient of relationship, for $A_1 + A_{12} = B_1 + B_{12} = r$. So if we examine the relatives we expect to find the defect appearing in one half of the parents, children and sibs; in one fourth of the grandparents, grandchildren, aunts, nephews, etc.; in one eighth of the first cousins; and so on.

⁸ L. S. Penrose, *Trans. Roy. Soc. Canada, Sect. V*, p. 93. 1940.

This is only true, however, if the gene is rather rare, if segregation is normal and if the gene always expresses itself when present. The last of these conditions is frequently contradicted in human inheritance; the gene is then irregular in its expression, producing the abnormality in only a certain fraction of the individuals in which it occurs. The study of the causes of this variation in expression is clearly one of considerable practical importance in medicine. In any case, we see that unilineal and bilineal relatives of the same degree are of equal value in the study of dominant genes.

When an instance of probable dominant inheritance is found, it is naturally advisable to attempt to trace the transmission of the gene through as many groups of relatives as possible. The distant relatives here become of interest not because they contribute additional information about the genetic constitution of the original patient but merely because they will very probably provide some additional affected individuals for study. The elaboration of extensive family histories is therefore not essential to detailed genetic study, but it provides an economical procedure for securing large quantities of material in the case of rare dominant conditions.

In seeking an answer to the question, Is such-and-such a condition hereditary?, it would perhaps seem most pertinent to ask: Was the condition inherited in the case of the patient? Attention is therefore immediately directed to the parents. Now of course an affirmative answer need not require that one or the other parent be affected. A "negative family history," at least with respect to the parents, is almost always expected in the case of recessive inheritance. It will also frequently be found in the case of irregular dominants. But even for regularly expressed dominant genes there is an additional reason for occasional or even frequent absence of an affected parent.

Every abnormal gene must have some starting point and such spontaneous changes from the normal gene are termed *mutations*. Tracing back any dominant gene through successive ancestral generations, we are frequently able to discover such starting points and, indeed, would always expect to find them if the pedigree could be extended indefinitely. On statistical grounds which need not be presented here, it can further be stated that the rarer the abnormality the more commonly will such "sporadic" cases appear, and especially so if the defect is associated with a lowered fertility. For example, Haldane⁹ estimates that about one in every three hemophiliacs has not inherited in the ordinary sense but represents an original mutation.

The realization of this fact is of practical importance for two reasons. First, a failure on the part of the clinician to report such cases will rob the geneticist of the opportunity of measuring one of the most fundamental of all genetic phenomena, *viz.*, mutation. Secondly, in so far as mutation is actually responsible for the exceptional cases, the defective patients must be regarded as the potential starting members of new family lines carrying the abnormal gene. Owing to mutation, then, it appears that the question, *Will the condition be inherited?*, is somewhat more significant than the question: *Was it inherited?*

So far we have somewhat slighted the importance of parents. Returning to our general formulae of genetic resemblance, we note that with $r = \frac{1}{2}$ we have the unique condition, $A_0 = 0$, and for this reason we may regard parent-offspring relationship as a special subclass of A-relationship. Parent and offspring *must* share one or the other of their genes: $A_1 = A_2 = \frac{1}{2}$. This commonplace is responsible for several genetical advantages in the comparison of parent and child. In the study of relatively common hereditary variations, pairs of parent

⁹ J. B. S. Haldane, *Jour. Genet.*, 31: 317, 1935.

and child will be generally somewhat more useful than pairs of brother and sister, and when both parents are included the information is usually increased very greatly. Also, the measurement of dominance or non-additive gene effects in the case of quantitative inheritance depends largely upon the comparison of parent and child.

Obviously the consideration of individuals as parents is essential to the investigation of the evolutionary factors of mutation, selection and population mating systems. In this last respect, man, because of the institution of marriage, possibly enjoys a distinct advantage over other species as an object for genetic study.

UNSELECTED DATA

There are two somewhat different methods for securing human genetical data. In the one procedure the investigator obtains an unselected sample of families or other groups of kin—unselected at least with respect to the characters in which he is interested. Obviously such a method will be found suited to the investigation of only such traits as are not too unequally distributed in the population or are of such a nature that selective sampling can not be conveniently employed. The ABO and MN blood groups, as well as taste reaction to phenyl-thiourea, are examples of traits which possess both of these features. For example, "tasters" and "non-tasters" occur in our population in about the ratio 7:3. This means that from one third to one half of all families taken at random (depending on their size) will show variation amongst the children and will therefore be of use in testing genetic ratios. However, even were such circumstances far less favorable, a random collection of data would still be in order by virtue of the fact that taste ability is a characteristic which does not make itself known to the subject

or the investigator until a special test is performed.

Inherited characters suitable to random investigation are therefore likely to be of the sort described as "normal" traits. Table I, which is reproduced from Wiener,¹⁰ summarizes a typical body of such data. One hundred families tested for the ability to secrete A, B or O agglutinogens in the saliva are classified here according to the three possible parent combinations. S denotes a secretor, and s a non-secretor.

TABLE I
HEREDITY OF THE "SECRETOR" FACTOR

Parents	Number of families	Children	
		S	s
S × S	51	134	21
S × s	38	64	44
s × s	11	0	28
Totals	100	198	93

The fact that non-secretor "breeds true" suggests the hypothesis of simple recessive inheritance of this property. To test the hypothesis we must then examine the ratios of S and s children in the two other matings, S × S and S × s. This might be done by first selecting from these matings all families with some s children. The analysis would then be similar to that described in the following section. If, however, it is desired to apply a test to the whole of the data, we must employ an analysis based on the computation of gene frequencies. It will be observed that the numbers of S and s children in the first two matings do not suggest any simple Mendelian ratios, such as 3:1 or 1:1. These, in fact, are not to be expected, for, on the hypothesis adopted, these matings must contain mixtures of different genotypes. This is an invariable feature of such data and it requires that we estimate the composition of such mixtures in terms of the gene frequencies. A wide variety of such

¹⁰ A. S. Wiener, "Blood Groups and Blood Transfusion," 2nd Edition. Springfield, Ill.: Chas. C Thomas, 1939, p. 191.

gene-frequency methods is now available for many kinds of inheritance and many kinds of data. The more important of these have been summarized by Professor Snyder.¹¹

In addition to their use in genetic analysis, gene frequencies are of considerable interest in themselves, as Dr. Strandskov has shown in a previous article in this series. It is therefore one of the advantages of randomly collected data that it facilitates the estimation of such gene frequencies. Fisher, however, has recently called attention to a complication in the determination of gene ratios which has not been considered by other authors. I should like to mention this point here since it involves the general topic of relationship.

Suppose we wish to estimate the frequency of the recessive non-secretor factor from the data of Table I. Since this is taken as the square root of the proportion of non-secretors, the problem is equivalent to estimating this latter proportion. Now if we consider the parents alone, the proportion is simply 60/200, while for the children we have 93/291. These two estimates are indeed very similar and ordinarily they would be combined to give 153/491. However, it would be incorrect to ascribe to this estimate, as is commonly done, a standard error equivalent to one based on 491 independent observations. An observation of two relatives will, in general, not carry the same precision as one based on two unrelated persons, but should have a weight varying between 1 and 2. This is easily understood in the extreme case where the coefficient of relationship $r=1$; 100 pairs of one-egg twins (200 individuals) are clearly equivalent to only 100 single unrelated individuals. The general procedure for estimating gene frequencies in data containing relatives has been outlined by Professor Fisher.¹²

¹¹ L. H. Snyder, *Eugenical News*, xix: 61-69, 1934.

SELECTED DATA

In the study of rare conditions the standard procedure is to examine only the relatives of affected persons who are encountered in a clinic, hospital, school or similar institution. After amassing data of this sort, the geneticist will then examine the frequencies of affected individuals amongst the various classes of relatives. Such a method of gathering data is obviously selective and might be expected to introduce some troublesome problems in connection with the statistical treatment. This is true, but it is interesting to note that the chief difficulty is one which arises only in connection with the sibs. That is to say, ordinarily the selection will not disturb the proportions affected amongst the parents, children, cousins, etc., but only amongst the sibs. This circumstance is traceable not to any genetic peculiarity of sibs but merely to the fact that the patient *himself* is to be included in the sibship.

The reasons for the disturbance of the sib proportions are explained very concisely by Professor Haldane,¹³ in the following manner: "If I asked every child leaving school in London this year how many brothers or sisters he or she had, and then calculated the average, it would be much higher than the average family size of London. First of all, I should have no representatives of childless families. Secondly, I should have ten times as big a chance of getting a child from a family of ten as from a family of one. So I should greatly exaggerate the number of large families."

In estimating the proportion of affected individuals in sibships we have a very similar problem. First, we omit cases where the parents could have produced a defective child but, by chance, failed to do so. This is easily corrected and need not worry the person who col-

¹² R. A. Fisher, *Ann. Eugen.*, 10: 160, 1940.

¹³ J. B. S. Haldane, "Science and Everyday Life," New York: Macmillan, 1940, p. 268.

lects the data. The second difficulty, however, is more serious. Let us imagine two sibships of 5 members each, one containing three persons with, say, harelip, and the other only one. Now the sibship of three affected members may or may not have a greater chance of being found than the sibship with the single member. If the search for families showing this defect were exhaustive, so that every harelip in the area sampled would be certain to be found, then both of our sibships of 5 would of course get on record. If, however, only a portion of the available harelips were encountered, the sibship of three defectives would have a greater chance of being recorded, since it might be brought to light through any one of the three individuals.

To rectify this difficulty we must, in effect, estimate what fraction of the available cases was studied. This would indeed be of considerable interest, for, in addition to disentangling our present problem, it might also lead to an estimate of the incidence of the disease in the general population. Fortunately, it can be done if the clinician takes care to record which of the affected persons were the original patients or *propositi*. More exactly, he should specify, for each affected individual, whether that individual was a primary or a secondary case, that is, whether the person was encountered individually in the clinic or school or whether he was only brought to light through an affected relative. Often a kindred involving several affected members will contain a single *propositus*, but occasionally two or more will have been

patients in the clinic or inmates of an institution.

The problem is clearly a very important one since, as we have seen, the sibs will always contain a large store of genetic information. Unfortunately, the marking of *propositi* is frequently omitted in the publication of family histories and much genetical value is therefore lost. In some kinds of studies it is possible that the classification, primary and secondary, will seem inappropriate; there might be more than two conditions of ascertainment or the unit might be a group rather than an individual. In such cases the investigator can do no better than to state exactly what these conditions were and trust that an appropriate statistical treatment can be devised.

SUMMARY

In conclusion, it would seem safe to say that any observations, to the extent that they are of value individually, will also be of value to the human geneticist, if only they contain relatives. Amongst relatives of the same degree, some kinds will be much more useful than others in the investigation of particular genetic phenomena. When the data are sought for unknown purposes or for several kinds of analysis, we can profitably adopt the rule that closest relatives are of greatest value. Even two relatives—parent-child, sibs, or twins—will often supply considerable information, though entire families are generally much preferred. Most important is the careful recording of the circumstances under which each person was obtained for study.

PERSPECTIVE OF PUBLIC HEALTH IN THE UNITED STATES

By Dr. J. M. GILLETTE

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THE possession of perspectives is perhaps the most significant symptom of intelligent and scientific competency. The great difficulty of the present time on the part of the masses and even the intellectuals and statesmen in economics and politics consists in obtaining sufficient facts and developing the organizing technique for realizing their full luminosity. Due to the fact that our health field has become so expanded and intricate and that our health efforts are highly individualistic and uncoordinated, our health perspective is liable to be blurred.

In seeking to establish a historical perspective of public health, pronounced limitations appear. Some things are clear and others are vague. Much of the story of mankind in matters of health are almost closed chapters. Except from observation of contemporary primitive peoples, we know next to nothing about man's hygienic and health status during the many hundreds of thousands of years of his preliterate days. But it is certain that the death rate just about equaled the birth rate during that period because the world's population remained small and dispersed. The fact that it required something like a million years for the world population to number about 900,000,000, while about one and a quarter billion inhabitants have been added during the century and a third since that time shows that during the most of man's earthly career he was scarcely able to survive the bitter struggle for existence. Foods were rough, famines were frequent, pestilence often ravaged populations, animal and human enemies took their heavy toll and births were relatively infrequent because of

long nursing periods which in turn were the outcome of crass foods unsuited to the young.

Recorded mortality rates do not reach far back into history, and we know nothing of morbidity rates until very recently. The latter would be a better criterion of the state of health of a people than the former because morbidities are so much more frequent than mortalities. Most persons get ill or incapacitated many times during their lifetime but die only once. The federal health survey of 1935 found that in this country on any winter day there are six million persons who are incapacitated from duties by illness or accident.

Since incapacities from daily morbidities from accidents are only a fraction of one per cent., all incapacitations may be thought of as arising from morbidity. Summer morbidities are much fewer than those of winter. Consequently, let us assume an average of 3,000,000 incapacitations a day throughout the year. This would give an annual rate of incapacitations from morbidities of 8,690. From these data and from the estimated number of deaths for any given day of the three heavy winter months, the calculation is made that on such a day there are 1,336 incapacities from morbidity for each death. But since we do not have published federal records of morbidities for our nation and states, we are compelled to study general health conditions by means of mortality data.

Records of European death rates begin early in the nineteenth century with two countries and increase in number of countries until there are eight in 1860 and 20 in 1930. The approximate aver-

age death rate for the three countries reporting for the five-year period 1808-1812 was 29.5, and the death-rate range was from 23.1 to 39.8. The eight countries reporting for the period, 1848-52, had an approximate mean rate of 22.6 and the approximate mean rate of the 20 countries reporting for the period 1928 to 1932 was 14.3 and their death rates ranged from 9.6 to 20.7. The decline of mean rates from 29.5 to 14.3 was quite regular, indicating an orderly and regular improvement in public health.

One might have expected a great drop in the curve after the germ theory of disease came to be adopted as basic to medicine and public health about the close of the last century. No such revolutionary incidence in medicine affected the mortality rate in an apparent manner. Probably the most important contributor to this result was the improvement in the amount of subsistence during that century which was made possible by the agricultural revolution and the industrial revolution. The masses had their food and other living standards increased and improved as never before. We are just now recognizing that improved nutriment is the greatest foe of disease and death. Of course medicine and sanitation by reason of antiseptics and improved engineering devices affecting water supplies and disposal of sewage also made their contributions. Life has been made safer in great cities, and in the United States the death rate in some of them is lower than that of rural populations of the same area.

There are "scientific guesses" that prior to the eighteenth century or thereabout, the mortality rates of these European nations must have been very much higher than those at the beginning of the nineteenth century. They were so high that they compelled a very slow population growth, which means that they about equaled the birth rates, which must have been very liberal. It is reckoned that in such great cities as London the

death rates were above the birth rates and that the cities grew only from attracting country people whose surplusage of inhabitants were the outcome of high birth rates and lower death rates.

The health picture of that age in general was probably similar to that of sample rural areas of China to-day. A recent survey of the Ting Hsien area, consisting of forty-four square miles and a population of 44,190, or an average of about 1,000 per square miles, reveals the following things. The inhabitants live in sixty-one villages, ranging from 100 to 2,600 per village. The average size of family farms is five acres and the average annual income is six to seven dollars (gold). The fifty-eight primary schools enroll 2,540 children at the general per capita cost of two dollars. Half of the sixty-one villages have a modicum and the rest have no medical facilities. Trachoma and ringworm, dysentery, summer diarrhea and typhoid fever are prevalent. Tetanus, neonatorum, smallpox and scarlet fever are the chief causes of death. There are no scientific checks on epidemics. The general birth rate is about thirty-two, and the general death rate about thirty-one. Thus the population is practically stationary.¹

Recorded death rates in the United States began in 1880 with the first registration area, consisting of two states, Massachusetts and New Jersey, and the District of Columbia, comprising about 17 per cent. of the population of the nation. What mortality rates were obtained previously can only be estimated roughly. An approximate idea of what they were during the first three decades between 1790 and 1920 may be obtained from the decennial population increase and the amount of immigration. The former was about 35 per cent. a decade, a rate of 35 per thousand a year. The immigration amounted to an average of 91,600 a decade, or about 5 per cent. of

¹ C. C. Ch'en, M.D., M.P.H., *McBank Mem. F. Quar. Bul.*, 11: 95-129, April, 1933.

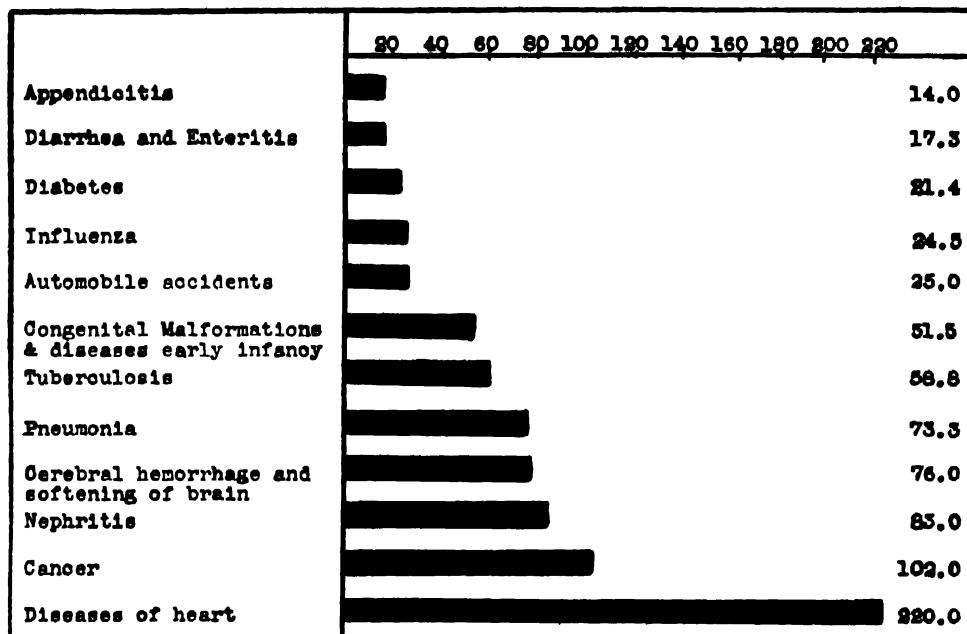


FIG. 1. MEAN DEATH RATE PER 100,000 FOR SPECIFIED CAUSES OF DEATH IN THE UNITED STATES FOR THE PERIOD, 1932-34. MEAN NUMBER DEATHS, U. S., 1932-34: 1,346,099. DEATHS FROM HIGH SIX IN CHART FOR SAME PERIOD 779,804—58.8 PER CENT., OF ALL. DATA FOR ESTIMATES FROM MORTALITY STATISTICS, 1932, AND FROM ADVANCED "RELEASE SHEETS" OF CENSUS BUREAU, 1936.

the amount of population gain. The difference between immigration and population increase represents the natural increase, the excess of births over deaths. This yields a rate of about thirty-three. To realize such a rate of natural increase demanded a very high birth rate. Were that rate fifty, the accompanying death rate would have been seventeen. Probably the latter was close to the real death rate then, for the farm population would probably average about 80 to 85 per cent. of all for the thirty years. This farming population had an abundance of land, food, fair housing, plenty of fuel and ample clothing. It was a well-kept population in terms of subsistence and should have sustained a relatively low death rate. Epidemics would constitute the great causes of death. The death rates would be much lower than those of European countries of that time because of the abundance of subsistence here.

Our crude death rate in 1880 was 19.8

per 1,000 of the population. In 1890, when the registration area included over 31 per cent. of the inhabitants and eight states besides the District of Columbia, the death rate was almost that of 1880, 19.6 per 1,000. The curve of the mortality rate fell very rapidly till 1900, and then still more rapidly and quite regularly on the average until by 1935 it was 11.0 for the 1880 registration area and 10.8 for the whole national area. Judging by the fact that the original registration area had a rate in 1935 which was almost exactly that of the whole national area, we might conclude that the rate of 1880 was representative of the whole nation. The only marked variation from the downward trend of the national mortality rate occurred in 1918 when the death rate mounted to about 18 from a level of about 13.5 in 1915. The large fluctuation was of course due to the "flu" epidemic of that period.

Are we to attribute the rapid fall of

death rates after 1890 to the placement of medical practice on the basis of the germ conception of contagious disease or to the inclusion in the registration area large sections of the best-conditioned farming states with their more ample subsistence levels? Certainly reduction of deaths from contagious diseases has greatly affected the general mortality rate. But we do not dare impute too much to that, since the fall in European death rates prior to the discoveries of Lister and Pasteur were about as marked and gradual as those subsequent to them.

This downward trend in mortality rates has been favorable to every age class of our population, although the gains to those under ten years of age are greater than those of any other age class. Between 1900 and 1932 even the aged, the population class of 75 and over, have improved their health status, as is indicated by their more favorable death rate. It is most satisfying to note that only a third as many infants proportionally die to-day as in 1900 and that the gains to those under five is even greater.

Are we to expect a continuation of the downward trend of the mortality rate in future of the same nature as that obtaining since 1900 or may it follow the horizontal henceforth or even make an ascent? The answer to this question is to be found chiefly in the changing age composition and in the changed nature of the chief causes of death which confronts medical care. The latter item will receive attention later in this article. Regarding the former, the import of age composition is seen in the statement that for a population with average length of life of sixty years and which, at the same time, is stationary (not increasing by excess of births over deaths or by immigration), the death rate must necessarily be about 16.7. Should our national population become stationary (predicted for the near future) and did we maintain our present average length of life (about sixty-three), then our death rate

will be forced up from the present ten or eleven to nearly sixteen. That might occur, however, without any deterioration in public health conditions.

A very considerable portion of health gains during this century have come from improved control of germ diseases. In 1935, contagious diseases accounted for 9 per cent. of all deaths, in 1912 for about 21 per cent. Some diseases, such as smallpox and diphtheria, have almost disappeared and tuberculosis has been robbed of its place as the leading man-killer.

The accompanying figure, Fig. 1, gives the picture of our twelve chief mankillers for a period of years, 1932-1934. The mean for the three years is used in order to obviate annual fluctuations.

These twelve causes represent 72.5 per cent. of all deaths during that period and therefore show where the chief health problem lies, so far as causes of death can denote it. The "big six," lower half of chart, account for 58.8 per cent., or nearly six out of every ten deaths. Diseases of the heart levy a death rate nearly sixteen times that of the lowest, appendicitis, over twice that of cancer, and nearly four times that of tuberculosis, formerly the chief cause of death. In 1935, diseases of heart, excluding coronary troubles, occasioned 19.5 per cent. of all deaths of that year. In this formidable list, only two contagious diseases appear, representing only 8 per cent. of all deaths. Deaths by auto accidents, very important, are a little over one a hundred of all deaths, and fortunately they have become proportionally less during the last two years.

The big fight in the field of health and medical care of the future, then, so far as mortality rates are an indication, is not to be against contagious diseases but against the nine non-contagious causes of the chart. Some of these greatest among man-killers are, as yet, under slight control. Various forms of heart

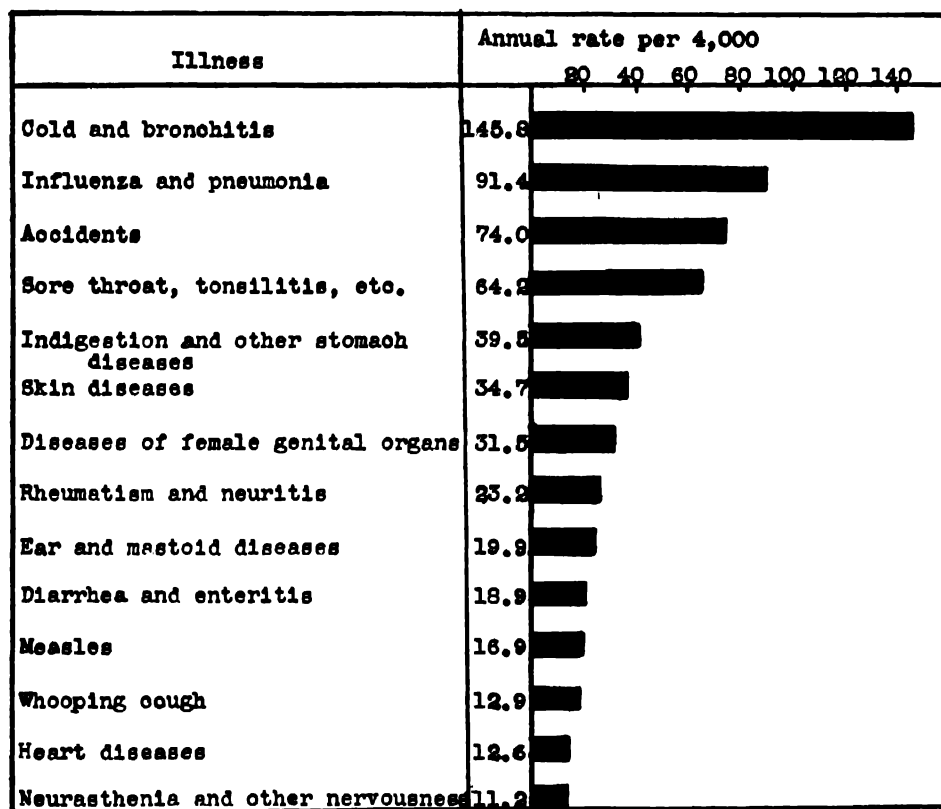


FIG. 2. INCIDENCE OF ILLNESS BASED ON NATION-WIDE PERIODIC SURVEYS, 1928-1931. REPRODUCTION OF FIGURE IN "THE NEXT STEPS IN PUBLIC HEALTH," MILBANK MEMORIAL FUND, BY EDGAR SYDENSTRICKER, N. Y., PAGE 31.

disease are not curable but only mitigable. And what is true of heart troubles is true of cancer generally. A large proportion of the most troublesome diseases are terminal in nature, develop with age and represent the accumulated scars contracted during the battle of life. We share in the scientific hope and expectation that ultimately all of them, one by one, will succumb to the discoveries of scientific workers and come wholly or in large part within control. What sulfanilamide and its derivatives are accomplishing in the field of pneumonia and elsewhere is a harbinger of what may be discovered and practiced for any of the others.

A comparison of a morbidity chart,

Fig. 2, with the one just noticed reveals quite a different set of causal factors as afflictions and incapacitators of mankind. In it germ and contagious diseases are observed to be the "big chiefs" of morbidity. Diseases of the heart have less than one eighth the force of colds and bronchitis, while cancer does not appear on the list.

The causal factors in morbidity may be given as follows: Germ and contagious diseases may be considered to be the "big chiefs" of morbidity. Diseases of the heart have less than one eighth the force of colds and bronchitis, while cancer does not appear to be a causal factor. These are the ailments and external incidents which incapacitate people for work and

duties. These are the predominant causes which incapacitate an average of 6,000,000 persons any winter day, according to the national public health survey of 1935-36. They also serve as the fostering foundation of many of the terminal diseases which trouble people in middle or later life. According to these morbidity data, and from the point of view of morbidity alone, the big health problem is one of controlling these ailments which incapacitate millions daily for duty, sap their vitality, cripple their economic efficiency and lay the basis for the inroads of more serious diseases later in life. It is a matter for debate which is the chief field for society to attack, the ailments presented in the mortality or morbidity charts. Viewed in relation to immediate life termination, mortality causes hold first place. But thought of quantitatively, in case number, and as incapacitating for functioning in life processes, morbidities are far in the lead, since, as was said, on any average winter day there are 1,336 incapacitating illnesses for every mortality.

Something that should be of profoundest significance to health workers is the distribution of death rates and the causes of such distribution among the states. Unfortunately, neither the general public nor the trained health fraternity has a really scientific and objectively determined comprehension of either, and especially the latter. With a very few exceptions, it is a guess regarding whether a regional change or if this or that region will act beneficially upon patients who have specific ailments. What we should know we do not know for two reasons: First, the facts relative to distribution have not been published in such form as to make them visual; second, the causes of mortality distribution in general and specifically have not been determined. This study has ventured into this field. It supplies available information concerning the distribution of several classes of mortality

rates throughout the nation by states, and it investigates observationally and statistically the field of causation accounting for the spread.

In order to iron out annual fluctuations, estimates have been made of mean crude death rates for general and specific causes of death for all the states for the three-year period, 1932-34. The specific rates are those of the six greatest man-killers. And so that the distribution patterns may be observed at a glance, they are embodied in cartographic maps, one for general mortality and the others for each of five specific causes. All maps are built on the same principle. The highest rates are represented by darkest shadings and the lowest by the lightest shadings, the others graduating between the extremes. For the benefit of the observer of the charts it seemed advisable to tabulate the class limits of the death rates of the maps in Table 1, since reduction in size for publication purposes has obscured them.

The range of variation in the general rate is from 7.9 in North Dakota to 13.7 in Nevada, per 1,000. The variations in specific rates (per 100,000) are as follows: In diseases of heart, from 102.1 in Arkansas to 381 in the District of Columbia; in cancer, from 44.5 in Arkansas to 157.5 in New Hampshire; in nephritis, from 44.8 in South Dakota to 141.9 in Delaware; in cerebral hemorrhage, etc., from 36.8 in Louisiana to 136.1 in New Hampshire; in tuberculosis, from 20.2 in Nebraska to 239 in Arizona; and in pneumonia, from 48.5 in Oregon to 119.6 in the District of Columbia.

A critical inspection of the general death-rate map (Fig. 3) makes some things apparent. We are struck by the absence of a dominant regional pattern. Most any class of mortality rates may occur most anywhere. The nearest to a dominant regional block lies in the northern Plains and Rocky Mountain region, a low rate area. But low rates also appear in the southeastern states.

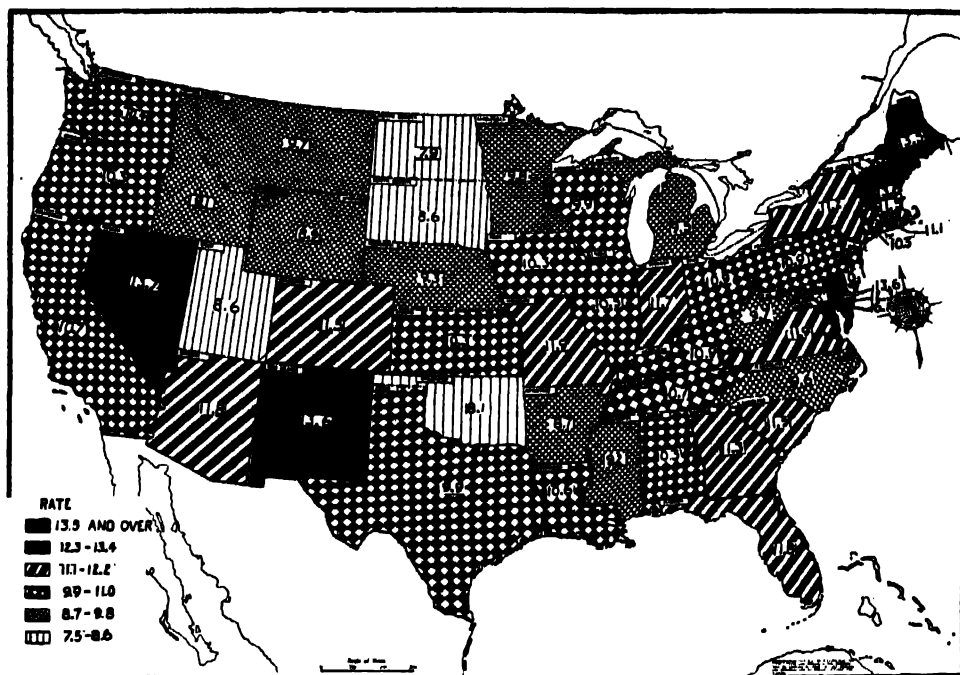


FIG. 3. MEAN DEATH RATE, UNITED STATES, 1932-34, BY STATES.

When the cause of this distribution pattern is sought, we become aware of two things: First, the presence of a *number* of determining factors, of which there are several classes—geographical, such as precipitation and temperature; biological, as seen in age composition; and cultural, evinced in migration of population between regions, per cent. of population that is urban, degree of schooling and per capita income. No one set or kind of condition accounts for all differences in distribution. Second, the determination of the exact weight exercised by any set of causal conditions can not be scientifically reckoned. This is typical of attempts to discover the exact division of labor among social forces which produce situations and problems. However, by means of this research effort we have learned something about causes of mortality distribution of both a negative and positive nature. It is possible to say that some factors are not important and that others are significant as causes.

A geographic determinist would not extract much satisfaction from a critical inspection of this spot-map. The medical man who wrote a book to demonstrate that differential death rates of North and South are due to differing climatic conditions evidently never confronted such an array of distributive mortality spot-maps as the series of this study reveal. If Ellsworth Huntington's "zone of energy" were based on death rates, it would be very partial. An attempt to explain the variation in rates solely by differences in physical environment immediately confronts confounding contradictions. Two sets of facts at once become obvious. First, states having identical climates, such as Nevada and Utah or Texas and Oklahoma, exhibit great extremes in death rates; second, identical mortality rates in states having most diverse geographical conditions, as seen in the case of North Dakota and Oklahoma or in that of Maine and New Mexico.

North Dakota is cold, dry, has long

TABLE 1
CLASS LIMITS OF SPECIFIED MEAN DEATH RATES, 1932-34

General per 1,000	Specific per 100,000					
	Heart	Cancer	Nephritis	Cerebral Hem., etc.	Tubercu- losis	Pneumonia
13.5 and over ..	340-383		125-144	118-139	106-239	48- 57.8
12.3-13.4	280-339	136-167	105-124	86-117	82-105	60- 74.9
11.1-12.2	220-279	104-135	85-104	74- 95	68- 81	76- 89.9
9.9-11.0	160-219	72-103	65- 84	52- 73	34- 57	90-104.9
8.7- 9.8	100-159	40- 71	45- 64	30- 51	20- 33	105-119.0
7.5- 8.6						

winters and a low precipitation rate of generally less than twenty, while Oklahoma is hot, generally has a rainfall much greater than North Dakota, has long summers and mild winters. The only common climatic element is low precipitation in the western portions of the states. On the other hand, take Montana and Mississippi, states having similar death rates, for comparison. Montana has a high altitude, is low in precipitation, has long cold winters, while Mississippi is the reverse in all particulars. New Mexico, with a dry climate, high elevation, almost no winter except in the mountain areas, is to be compared with Maine, which is the opposite in all these respects. In the same manner we observe other pairs of states, such as Maine and Nevada, Wisconsin and Texas, etc.

The similar high rates of Maine and New Mexico are to be explained probably in large measure with respect to age composition and migration, the latter being in turn a large cause of the former. In New Mexico, 43 per cent. of the population in 1930 was between the ages of five and twenty-five, the period of lowest death rates, while in Maine but 35.5 per cent. of the inhabitants were so aged. In contrast, the percentages of persons who were sixty years old or more, the age period of greatest death rates, were 7.4 in New Mexico and 12.8 in Maine. This alone would place Maine high in the death-rate list. Both states have been influenced by migration. Maine has lost younger people to the West formerly and to eastern cities more recently, while New

Mexico has received young inhabitants. This helps explain why the Maine population is older than that of New Mexico. Into New Mexico also have migrated many tuberculous and perhaps other ailing individuals, many of whom have died there and swollen the death rate. This goes far to explain the high mortality rate there. The geographical factor in the case of New Mexico appears as an indirect cause of the high death rate. Its favorable climate has attracted the diseased individuals who have died there, but the climate did not kill them.

One is apt to think that the explanation of the distribution of specific death rates would be comparatively simple, as the case of death from hookworm. But such is not the case, as a review of the situation in some detail suffices to show.

Fig. 4 shows how mortality rates from diseases of heart are reported by the federal census. Variations are pronounced, but there seem to be regional patterns. The areas of highest and high rates are northeastern and extreme western United States, the Plains, eastern Rockies and South generally showing lowest and low. A physician might very well advise his heart patients, if a change were thought desirable, to go to the South or to the extreme central North.

The tendency among those who see these charts is to explain mortality distribution in terms of climatic conditions. Causatively, climate does not appear to amount to much as an explanation of this distribution. Regarding temperature, low death rates obtain in numerous

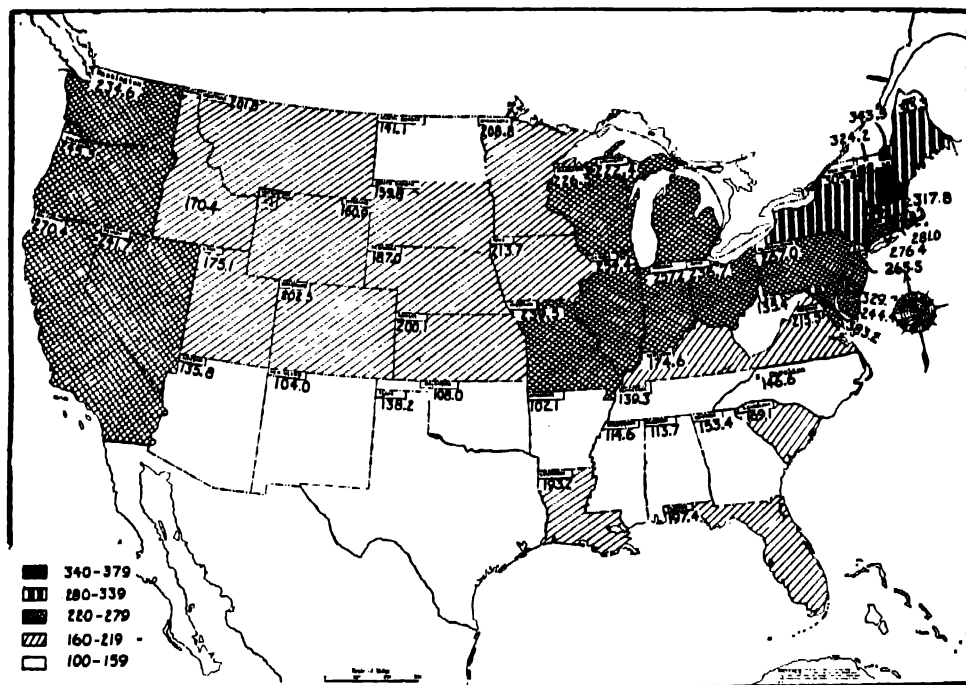


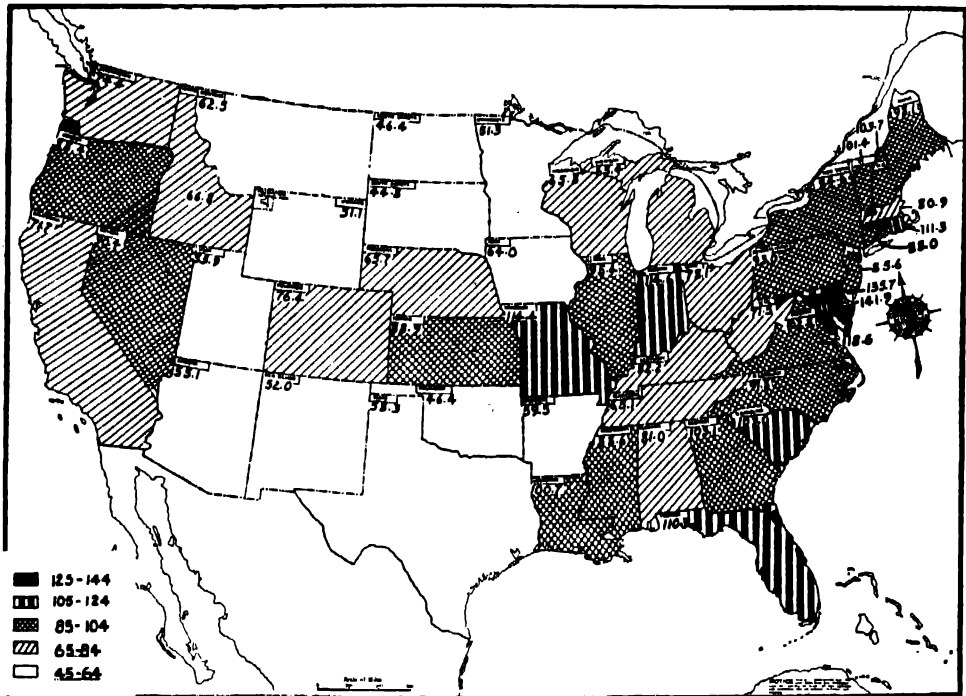
FIG. 4. MEAN NUMBER OF DEATHS PER 100,000 FROM DISEASES OF HEART, UNITED STATES, 1932-34.

cases in hot and cold regions, and the same is true regarding precipitation or moisture. One can not claim too much for cold or dry as being conducive to avoidance of heart troubles. This conclusion is substantiated by applying the method of correlation to two sets of variables, that of heart death rates among the forty-eight states and District of Columbia as one series with each of two others, mean temperature and mean precipitation. The former gives a coefficient of -0.27 , with a probable error of $.09$ and the latter one of -0.04 , with a probable error of $.10$. Since in both cases the probable error is more than a fourth of the coefficient, the latter has little or no significance. It is understood that correlation is useful, when intelligently applied, as a clue to causal relationship obtaining between series of variables.

Cultural environmental factors do appear as influential in explaining the distribution pattern. Both per cent. of population that is urban among states

and the per capita income among states, when correlated with the heart mortality series yield highly significant coefficients. The coefficient of urbanism with heart death rate is 0.75 , with a probable error of $.04$. That of heart death rate with per capita income is 0.73 , with a probable error of $.05$. These mean that the greater urbanism and per capita income are, the higher is the death rate from heart disease. Thus both coefficients are significant. But the coefficient between urbanism and per capita income is 0.79 , indicating that they are closely associated. To discover what is what, an application of partial correlation, when per cent. urban is held constant, yields a coefficient of 0.34 , with a probable error of $.085$. Thus it is shown that it is not the per capita income but the degree of urbanism that is the important causative factor. We conclude that heart mortality rates graduate upward with per cent. of population which is urban.

The distribution of the death rate



After consulting Fig. 6, showing the distribution of the mortality rate from nephritis throughout the states, a physician would be inclined to advise patients to avoid the area east of the Mississippi generally and the Pacific coast region and to settle most anywhere within the Great Plains and eastern Rocky Mountain areas, with the exception of Louisiana, Missouri, Kansas and Nevada. But if he justified his advice on grounds of climate, he would overlook some very contradictory facts. The cold and dry northern plains and mountain states

have the same low death rates from nephritis as do the hot moist states of Arkansas and Alabama, while hot states like Arizona and Florida have most divergent rates. If he were wise and honest he would say he does not know why, but supposes there are influential social environment factors which also intervene. Or if he were statistically inclined he might try out some correlations. Then he would find a somewhat significant coefficient between nephritis death rate and temperature of 0.44, with probable error of .09, and a more significant one between death rate and precipitation of -0.67 , with a probable error of .07. His explanation would then be that to a small extent nephritis mortality increases with temperature, but to a considerably greater degree it decreases with the amount of precipitation. The ultimate whyness of that he would have to tussle over. The use of correlation on the data we have do not reveal

what socio-cultural factors are influential causes. But since climatic conditions do not fully explain and do raise contradictions, we suppose the other factors are modifying agents.

There is no striking regional pattern or patterns relative to mortality rates from cerebral hemorrhage, etc., among states. (See Fig. 7.) The highest rates are found in Maine and New Hampshire, next highest in Vermont, Maryland, Virginia, Ohio and Indiana. Low rates are scattered from Atlantic to Pacific Coasts and from Canada to Mexico. Rather obviously neither climate nor topography, temperature nor moisture, have paramount determinative influence. Statistical application of methods of correlation result in nothing at all significant. There is a correlation coefficient of 0.40 with a probable error of .08 between this death rate and per cent. of urbanism, showing that living in cities or some factor or factors in urban residence perhaps are caus-

ative factors. A more significant coefficient results from correlating hemorrhage death rates with the per cent. of population between ages of five and fifty-four, one of -0.51 , with a probable error of .07. This would read that the greater the per cent. of inhabitants in that wide age period, the one with a uniformly low death rate generally, the lower is the mortality rate from cerebral hemorrhage. If the physician advised such patients to keep out of Maine and New Hampshire, the states with highest death rates from this cause, he should not do it because of climatic reasons, for they probably have little to do with the case. In fact, he would have little reason for giving such advice, since it is likely that the heavy migration of younger persons out of those states has left an exceptionally large portion of those who are in upper age levels and so who are especially addicted to attacks of cerebral hemorrhage. It is a biochemical rather

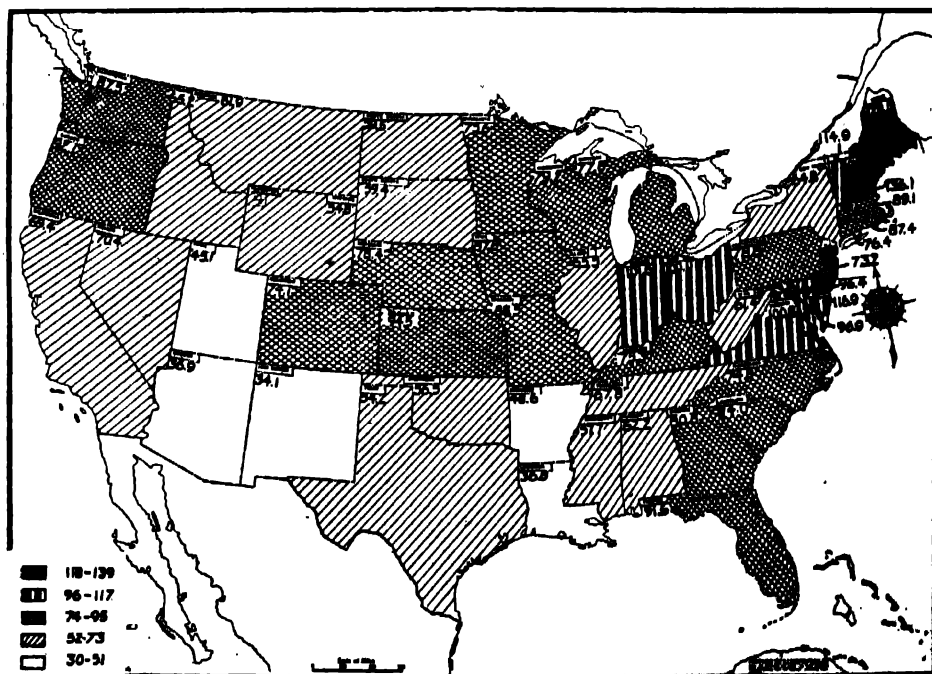


FIG. 7. MEAN NUMBER OF DEATHS PER 100,000 FROM CEREBRAL HEMORRHAGE, ETC., UNITED STATES, 1932-34.

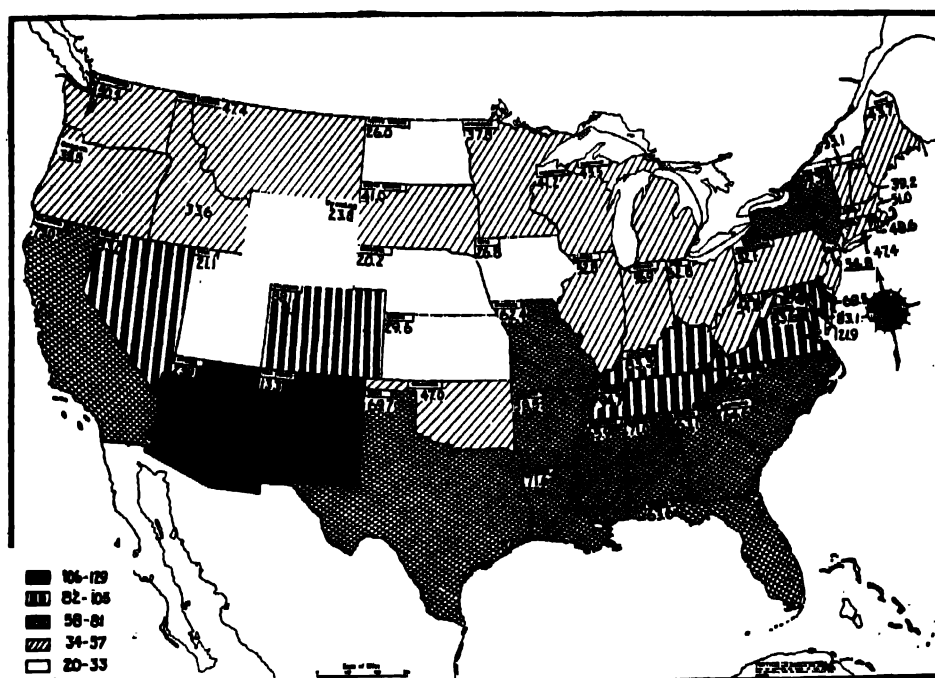


FIG. 8. MEAN NUMBER OF DEATHS PER 100,000 FROM TUBERCULOSIS, UNITED STATES, 1932-34.

than physical or cultural environmental matter.

Regionality shows up strongly in the spot-map of tuberculosis (Fig. 8). All the highest death rates from that disease, all the next highest, and most of the medium rates lie in states south of the northern tips of Nevada, Colorado, Missouri and Maryland. There is only one medium rate state, New York, north of that line. The six lowest rate states are Kansas, Utah, Iowa, Nebraska, Wyoming and North Dakota. The most southerly next lowest rate state is Oklahoma. On the surface, medical advice to tuberculosis patients as to location would be to avoid the low-rate states, probably for climatic reasons.

Yet here again, as in previous instances, most contradictory situations crop up. Here are states identical in class of rates but fundamentally and widely differing in climatic conditions: Nevada and Colorado on one hand and

Maryland, Virginia, Tennessee and Kentucky on the other. There are also North Dakota and Utah, Montana and Oklahoma. New Mexico, with a rate of 133, and Arizona, with one of 239, stand highest in rates, yet these high rates are only indirectly due to climate. Tuberculosis patients repair there to avoid the disease and just happen to die there and so run the state rate up. What is true of them is only less true of Nevada and Colorado. How largely migration to supposedly favorable climates affect the death rate of other states is indeterminate. Evidently low temperatures are not unfavorable to tuberculosis, since it is the northern states generally which show low rates and the state with the lowest mean temperature, North Dakota, is only fourth above the lowest tuberculosis death-rate state.

Coefficients of correlation are favorable to the idea that climatic conditions have a good deal to do with distribution

of tuberculosis mortality rates. That for temperature and tuberculosis death rate is 0.58, while that between the latter and precipitation is 0.59, the probable error in each case being .06. Thus the tuberculosis death rate varies directly with temperature and the amount of precipitation, remembering the notable exceptions which were indicated.

Due to mutilation of the spot-map of pneumonia, the visual picture of death rates from that disease can not be presented. But the states have been grouped according to rate classes, and the mode of spread noted. Seven of the nine geographical divisions of the United States with eight states and all climates are represented in class one; nine divisions, twenty states and all climates in class two; five divisions, twelve states and all climates in class three; three divisions, seven states and all climates in class four; and the District of Columbia alone in class five. There is no large block of states with similar rates anywhere and no distinctive regional pattern. Further, in testing the matter by

correlating the series relating to temperature, precipitation, per cent. of urban population and per cent. of inhabitants in ages five to fifty-four, no coefficient which is at all near significance is obtained. The conclusion is inevitable that no region or climate in a large way appears advantageous for pneumonia patients. However, one might think that the three areas, Arizona, Delaware and the District of Columbia, whose rates range from 100 to 120, are either disadvantageous in some way or that afflicted persons flock there to live or for hospitalization. On the other hand, the physician might have good grounds to advise his patients to seek relief in any one of these states whose pneumonia death rates are under sixty, placed in order of ascending rates from 48.5 to 57.8: Oregon, Washington, Kansas, Wyoming, Kentucky, South Dakota, Mississippi and Nebraska. It is to be noted that hot and cold, dry and wet climates are present in this favored group of states.

TWENTY-ONE COLLEGES EXAMINE THEMSELVES

IN advancing the frontiers of learning, the physical, biological and social sciences have overthrown many of the old authorities and have challenged the ideas, the values and the beliefs that gave order and coherence to the older scheme of knowledge. The present chaotic character of higher learning is the direct result of the breaking up of the established pattern of culture. There are some who believe that the broken pieces can be reassembled. For them education's whole duty is to conserve and transmit the cultural inheritance from the past and to remain loyal to the traditional disciplines of liberal learning.

There are others who would make a negotiated peace. They do not ask for a return to the old order, but they would like to correct the unbalance between technical training and liberal culture. They believe that science and scientific method should be counterbalanced by philosophy, religion, literature and art. . . .

There are still others who have complete confidence in scientific knowledge but lament the backwardness of the social and biological sciences as compared with the magnificent advance

in our control of inert matter and our knowledge of the physical world. For them the primary task of education is to explore the wilderness of social relations and the human mind. They believe that the answer to our problems is more knowledge. . . .

And finally, there are those who are excited by the riches of the new world, and embrace it for better and for worse. They welcome the advent of new patterns of knowledge and an indigenous American culture. They would let the dead bury the dead while they rally to the defense of the new order. For them there is no time to lose. The cause of freedom and democracy is in peril. It is only by education for democracy that the future can be made secure. They think of democracy not as a station but as a road, not as a status but as a process, not as a resting place but as a pilgrim's progress. They see in it man's brightest hope, the future's seal, the coming day of salvation. They have the conviction that this is the new integrating principle, the new way of life we must find and teach.—*William P. Tolley, The Educational Record, July, 1941.*

KARL PEARSON: FOUNDER OF THE SCIENCE OF STATISTICS

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THE death of Karl Pearson in 1936 ended the career of one of the most influential scientific figures of the present century. His influence has been due not to sharply defined and dramatic discoveries in science, but to the development of a methodology for investigating many phases of biological and social science with greater objectivity than had been possible before. There had been forerunners of this new methodology such as the early English school of political arithmetic, the German school of state-science and the French school of probability, but it was Pearson and his pupils who combined the principal ideas advanced by these earlier schools and founded the science of statistics as we know it to-day. The statistical method of investigation developed by Pearson and his school and subsequently expanded, refined and reoriented in some respects under the leadership of R. A. Fisher has been adopted as a fundamental part of the procedure of inquiry in many branches of social and biological science. Whether we look into the literature of genetics, eugenics, medicine, public health, agronomy, entomology, psychology, economics, quality control of industrial products or any one of many other fields, we find frequency curves, correlation coefficients, chi-squares, standard errors and other Pearsonian tools of statistics.

It is difficult to give even a rough indication of the extent to which Pearson's ideas and methodology have entered into the development of these various branches of scientific investigation without mentioning a few facts about Pear-

son's activities and the status of biological and sociological science at the beginning of his career. Born in 1857, he was trained in the traditional Victorian manner in mathematics and philosophy at Cambridge in the late 1870's. In 1880 he was made a fellow of King's College, which assured his financial independence for several years. The next five years represent for Pearson a period of intense intellectual activity and a great widening of his interests. Undoubtedly influenced by his father's profession, Pearson was called to the Bar in 1880 and established headquarters for legal studies in Inner Temple in London. During the next few years he made several trips to Germany, became interested in the history of the Reformation and German thought and social life of that period. Between 1882 and 1884 he delivered several series of lectures and wrote a number of articles on his findings in German historical research, all of which were later consolidated into "The Ethic of Freethought," and published in 1888. In this piece of work, we can see Pearson's youthful idealism shaping itself into "that faith of a scientist which formed the basic philosophy" of his life. At the same time he was collecting material on the German Passion Play, which was used later in "The Chances of Death." Despite his ventures into the social studies at this period, his mathematical talent was by no means idle, for he was busy writing papers on the motion of fluids and other topics in the mathematical physics of that time. In 1884 he was appointed to a professorship of applied

mathematics and mechanics at University College, London. Here we find him continuing his research in mechanics, as well as completing Clifford's "Common Sense of the Exact Sciences" and Todhunter's "History of the Theory of Elasticity," both of which were left in fragmentary form by the deaths of the authors. In addition to the scientific value of completing this work, it helped crystallize in Pearson's own mind many ideas regarding the fundamental concepts of science which were developed in a course of lectures given at Gresham College and later revised and published as "The Grammar of Science" (1892). This work is, and will probably remain for a long time to come, one of the classics in the philosophy of science. In it, he attacked the dogmatism of the past and stressed the need of eliminating from science any jurisdiction which theology and metaphysics may claim. He went a long way toward unscrambling many points of confusion which existed in nineteenth century scientific thought by discussing and developing the idea of the necessity of strictly limiting the domain of science to an objective description of the "how" rather than the "why" of phenomena, regardless of the nature of the phenomena. "The Grammar of Science" gives a remarkably clear picture of the scientific idealism which was to characterize Pearson's later work. The function of science to Pearson was "the classification of facts, the recognition of their sequence and their relative significance." To him "The unity of all science consists alone in its method, not its material." For his motto, he adopted the well-known words of Galton: "Until the phenomena of any branch of knowledge have been submitted to measurement and number it can not assume the status and dignity of a science."

There is little room to wonder that in his later years Pearson, so strongly

bound to these philosophical principles, should have turned his attention to problems in such a variety of fields. Within a few years after his appointment to the professorship at University College we find Pearson, heavily influenced by W. F. R. Weldon and Francis Galton, beginning an extensive series of mathematical and statistical investigations into inheritance and evolution. Knowledge in this field up to now was mainly descriptive and had not been subjected to numerical treatment. The extent of Pearson's written contribution to the study of these problems is amazing. During the period 1893-1901 he published in the *Philosophical Transactions of the Royal Society of London* about thirty-five papers and memoirs on these studies and on the mathematical problems which grew out of them. It was in this program of research that he made his greatest contributions to statistical theory. He developed the theory of multiple and partial correlation based on normal multivariate populations, introduced curve-fitting by the method of moments, evolved his system of frequency curves, derived the famous Chi-square Test of Goodness of Fit, deduced many standard error formulas, and carried out many other investigations in theoretical statistics. Users of modern statistical tools familiar with Pearson's work who will stop to examine the concepts underlying the use of their methods will surely be impressed by the extent to which Pearson contributed to this body of tools. Of course much has been done in recent years in the further development and refinement of the mathematical tools of statistics, but without carefully considering the embryonic nature of statistical method before Pearson's time, it is difficult not to overlook the full significance of his original work in mathematical statistics.

Pearson was so vigorous and unswerving in his scientific pursuits that

he was frequently involved in controversy. One of the most bitter controversies of his career arose over the biometrical versus the Mendelian approach in genetics. The Mendelian hypothesis regarding the mechanism of heredity was rediscovered in 1900 after Pearson had advanced to a rather late stage in his biometrical study of inheritance. Some of his papers and views were severely criticized by Bateson, a vigorous personality of the Mendelian school, and this opened the controversy which lasted for four or five years and resulted in a virtually complete divorce between the approaches of the two schools to the study of heredity. This was perhaps unfortunate because it now appears that the Mendelian and biometric methods are, to a considerable extent, of a complementary nature rather than fundamentally incompatible. One of the results of the Bateson controversy was the founding of *Biometrika*, a journal which has played a leading rôle in the development of statistical methodology.

In 1906 after the death of Weldon, who had inspired Pearson in his study of heredity and evolution, Pearson began to turn his attention from the general principles of heredity to Galton's infant science of eugenics and to the creation of a research institute where the ideas and techniques which Pearson had been advancing in rapid succession during the previous years could be carried on under more stable conditions and built into an independent and established branch of science. The result of his efforts was the foundation of the Biometric and Eugenics Laboratories, which were formed in 1911 into the Department of Applied Statistics. Thus in 1907 we find Pearson at the head of the Department of Applied Statistics, in charge of the Drawing Office for engineering students, giving evening classes in astronomy, directing two research laboratories and editing *Biometrika* and other series of publications. This was indeed an enormous task

for one man and could have been done successfully only by a man possessing his power of concentration and his ability of rapidly shifting his mind and attention from one subject to another. It was not until 1911 that he gave up his chair in applied mathematics to give his full time to statistical studies.

To give even an outline of the research work initiated by Pearson in his laboratories between 1906 and the outbreak of the World War, is beyond the scope of this sketch. However, most of this work can be roughly classified according to three headings: (1) memoirs concerned with the collection and analysis of fundamental data regarding inheritance; (2) memoirs in which statistical methods were used in an attempt to throw light on important social and eugenic problems of the time; (3) contributions dealing with statistical theory. The research done in (2) involved Pearson in various prolonged controversies. Included in this group of research projects were studies of claims made by various organizations and societies, some of which were sponsored by the medical profession, on the prevention of tuberculosis, on the effects of alcoholism, on the eugenic betterment of the race, etc. Much of the literature issued by these societies was propaganda based on ill-founded facts or none at all, and it was this type of authoritative dogma that Pearson rebelled against in "The Grammar of Science," and which continued to irk him throughout his life. For example, one of the problems which Pearson investigated was whether there was any evidence that the alcoholism of parents had any marked influence on the mentality and physique of their progeny during childhood. His conclusion, based on data from Edinburgh and Manchester families, was that there was no marked influence of this kind. The publication of this result created a terrific controversy in which economists, medical men who had denounced alcoholism at some

time or other and platform orators of temperance organizations joined in a chorus of protest and criticism. Undaunted by these critics Pearson only gathered more evidence and challenged them to refute his conclusions scientifically. This is only one of many fights in which Pearson became entangled then and later.

The contributions of the pre-war period dealing with statistical theory arose quite naturally out of Pearson's many statistical investigations. Almost all this work has been published in *Biometrika* or as separate publications issued by the Biometric Laboratory with the financial assistance of the Worshipful Company of Drapers. One important phase of Pearson's program was the preparation of an extensive series of statistical tables, and the first significant achievement here was the completion of "Tables for Statisticians and Biometricians" in 1914.

The outlook for the work of the Biometric Laboratory early in 1914 was better than it had ever been: a new building had just been completed; lectures were well attended; able students were being drawn from various parts of the world; many projects were under way; a growing body of opinion in various branches of science was learning to appreciate the value of statistical methods. With the outbreak of the European war, this whole program was disrupted, although some of the work such as the editing of *Biometrika* and research in statistical theory was continued on a small scale. Pearson placed his calculating facilities at the disposal of the Government, and his new building was used as an extension of the University College Hospital for the wounded.

After the war, Pearson, now in his sixty-fourth year, resumed his program at the new Galton Laboratory with his characteristic vigor and capacity for hard work. A considerable number of

new enterprises were started and successfully completed before Pearson's retirement in 1933. Among these projects we find, "The Tracts for Computers," dog-breeding experiments, work in anthropometry and craniometry, finishing the "Life of Francis Galton" which was started before the war, founding of the Galton Museum and of the *Annals of Eugenics*. It is difficult to realize that all this new work was carried on under the personal supervision of a man between his sixty-fourth and seventy-seventh years and was done in addition to his lecturing and editing of *Biometrika*. He resigned his chair in 1933 and continued some of his work in retirement until his death in April, 1936. His Department of Applied Statistics was divided into two independent units—a Department of Eugenics with which the Galton professorship would be associated and a Department of Statistics. The two new departments are now headed respectively by R. A. Fisher and E. S. Pearson.

In his recent biography entitled "Karl Pearson,"¹ E. S. Pearson has given a most illuminating and carefully

¹ E. S. Pearson, "Karl Pearson," Cambridge University Press (1939). This biography is essentially a reprinting of two long articles of the same title originally published in *Biometrika* in 1936 and 1937. Since these articles were written primarily for the readers of *Biometrika*, the emphasis has been placed on the scientific life of Karl Pearson. The book is well documented by letters, photographs and extracts from the work of Pearson and his associates. An interesting feature is the addition of two appendices which did not appear in the original *Biometrika* articles. The first of these contains detailed syllabuses of thirty lectures on the "Geometry of Statistics" and the "Laws of Chance" delivered by Pearson to a popular audience at Gresham College between 1891 and 1894. The second appendix was prepared by G. Udny Yule and contains a summary of subjects dealt with by Pearson in his lectures on the "Theory of Statistics" when Yule was a pupil of Pearson's at University College in 1894-96. The book also includes a partial bibliography of 122 articles, books and memoirs written by Pearson.

interpreted account of the motives, methods and accomplishments of his father. He has portrayed his father "as the historian, the writer on folk-lore, the socialist, the applied mathematician who discussed problems of elasticity and engineering . . . , as the author of 'The Grammar of Science,' as the biometrician, statistician and eugenicist, as the teacher and the biographer." It is per-

haps safe to say that Pearson's greatest contribution to science is not his work in any particular one of these fields, but it is the methodology which he has developed and illustrated again and again for handling problems in these and many other fields of a similar nature. He "has made the calculus of mathematical statistics a real factor of practice in vast fields of scientific inquiry."

AMERICA'S FIRST ATTEMPT TO UNITE THE FORCES OF SCIENCE AND GOVERNMENT

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ONE hundred and twenty-five years ago this month (June, 1816), there was organized in Washington, D. C., a society for the promotion of the arts and sciences which came to be known as the Columbian Institute. So ambitious was its aim, and so pre-eminent were its leaders, that a brief review of this early scientific society may be of interest in times like the present.

The two leading spirits in organizing the Columbian Institute were Dr. Edward Cutbush and Thomas Law. At the opening meeting, June 1, 1816, Dr. Cutbush declared that the time had come in this young nation to organize the scientific minds of the country and place their services at the disposal of the government. "We would," he declared, "foster the arts and the sciences, and develop them for the benefit of all people. . . . There is scarcely an art or science that cannot be benefited by this society. . . . The science of chemistry is to be given special attention since it is considered the handmaid of the arts, and is intimately connected with almost every branch of human knowledge; the arts, agriculture, and manufacturing."¹

¹ Richard Rathbun, *U. S. National Museum Bull.*, 101: 12, 1917.

This young scientific society immediately attracted the attention of leading men everywhere. Numbered among its members were John Quincy Adams, who for many years was America's greatest patron of science; John C. Calhoun, who had not yet become too deeply absorbed in the philosophy of states' rights; Henry Clay, who soon would be proclaiming his great American System; Andrew Jackson, who later was to view with alarm too much governmental interference in private affairs of any kind; Joel R. Poinsett, soon to rank among the leading scientists of the South; Charles Wilkes, who later was to gain renown as leader of the famous Southern Pacific Expedition, and who during the Civil War captured the British steamer *Trent*, and arrested Mason and Slidell as they were fleeing en route to England; William H. Crawford, Richard Rush, William Wirt, John McLean and others of equal importance.

The membership also included the names of fifteen United States Senators, twenty-eight Congressmen, six Cabinet members, two foreign members, army and navy officials and others holding important positions in the nation's capital. There were also doctors and lawyers, architects and bankers, educators

and gentlemen of the press. Almost everybody in Washington, if he was a man of prominence, belonged to the Columbian Institute. Aside from the resident members, there was a galaxy of honorary members, including Jefferson, Madison, Lafayette, Baron Cuvier and President Monroe. Outside of Washington, men prominent in science and learning were also invited to join.

Congress early granted official recognition to the Columbian Institute. By an act passed April 20, 1818, the Institute was legally incorporated, and given permission to hold its public meetings in the House of Representatives.² The Institute had no home for six years, but finally in 1824, Congress granted it permanent quarters in the Capitol—a large room under the library. In an act passed May 5, 1820, Congress further favored the Institute by granting it five acres of public land in the Mall, immediately west of the Capitol. The land was used as a botanical garden. An additional grant of land was voted May 26, 1824.³

The Columbian Institute got off to a good start. Its membership, as we have seen, consisted of many of the ablest men of the time. They were ambitious to serve their young, growing nation. Incorporated in the Institute's constitution were such notable objectives as that of collecting, cultivating and distributing the products of this and other countries, in order to promote domestic arts and manufactures; to collect and discover the various mineral products of the country; to invite communication on agricultural subjects; to obtain a topographical and statistical history of the different sections of the United States, their rivers, agricultural products, the climate and the arts and manufacture

best suited to each particular region. Finally, when the Institute had collected a sufficient amount of important data on these various subjects, information that would be of value to the public, it was to be printed.

In addressing the Institute on January 11, 1817, Dr. Edward Cutbush, its first president, struck a popular note when he declared that there was scarcely an art, science or manufacture which might not be benefited by this association. He congratulated the Institute on having so many members who were able and willing to help in establishing botanical gardens, collect mineralogical cabinets, build up a library of science, and make this organization assume high rank among the scientific associations of the world. This country, he declared, afforded unlimited opportunities for new discoveries. He believed there were a sufficient number and variety of plants native to our soil, which if properly processed would make it unnecessary to import those now demanded by our physicians and our dyers. Our minerals should be used for something more than to decorate cabinets. The mineral resources of this country were waiting to be exploited. Metals, clays and marbles useful to the artist and the manufacturer, and pigments waiting to be manufactured from the ores, were lying untouched.

Members of the Institute were asked to help in introducing and cultivating coffee, sugar, various dyeing drugs, the cochineal insect, the silkworm, the sunflower, the white poppy and other plants. "Should we be enabled to introduce a single grain, or one grass, which will afford a greater proportion of nutrition than those we now possess, millions may be produced to our country." The files of the patent office, he declared, bore ample testimony to the genius which prevailed in all parts of our country. "Where genius and talents are respected

² *Annals*, 15th Cong., 1st Sess., 1777, *Appendix* 2594.

³ *Annals*, 16th Cong., 1st Sess., 2585; and 18th Cong., 1st Sess., 787.

and rewarded, the arts and sciences will flourish, and the wealth and power of nations increase."⁴

The Institute's main purpose was to put science to work. Applied science, not theoretical science, was the chief aim. Its plant collections consisted of living plants—plants that could be used in the interest of medicine or for food value. Its collections of minerals were studied with reference to their usefulness in the arts, industries and manufacturing. Reports on agricultural experiments were solicited so that they might be passed on to all farmers and live-stock growers. In brief, here was the nation's first concerted effort, on a large scale, to organize the scientific knowledge of America and utilize that knowledge in a practical way. The titles of the papers read at the different meetings reflect this idea continuously. Papers relating to the culture of the silkworm, chemistry in agriculture, plant culture, improved ship-building, bellows for pumping foul air out of ships, the fixing of the first Meridian, the establishment of a system of weights and measures were read, and others of similar nature.

John Quincy Adams, while President of the United States, found time to attend several meetings of the Columbian Institute. He noted in his *Diary*, December 31, 1827, that he had that day attended the anniversary meeting, and was favorably impressed by Mr. Southard's address. "He (Mr. Southard) was about an hour in delivering it, and gave very general satisfaction. It was on the obligation of the government of the United States to patronize sciences. Southard argued the cause with great zeal and ability, urging it as a duty resulting from our situation among the nations of the earth, and recurring especially to the expressed opinions of Wash-

ington, Jefferson, and Madison."⁵ President Adams went on to say that he himself gave a toast at this anniversary dinner, "To the Cause of Science," which were the first words of Mr. Southard's address.

It might be noted in passing that the Institute had no more loyal supporter at any time than President John Quincy Adams. Even after he was retired from the office of the president in 1828, he kept up his interest and with some regularity attended the meetings of the Institute. In his *Diary*, under date of January 16, 1830, he made extensive notes upon Edward Everett's anniversary address, which was given on that occasion. Adams described it as a literary, philosophical and scientific masterpiece. It was, "a description of the most important modern inventions and discoveries, and of the manner in which they had been made, with several interesting anecdotes relating to discoveries and inventors."⁶

Of all the papers read before the Columbian Institute during the twenty-two years of its history (Rathbun reports a total of 177), the one by the distinguished Edward Everett was the most significant. He gave this same address, with some modifications, on numerous occasions and before different groups in different sections of the country. It is worth noting a few of the main points found in that remarkable essay. Science and education, he declared, were as necessary to the artisan and the mechanic as to the philosophers. All useful arts should be carried to the highest point of attainable perfection. Many evils, he pointed out, had resulted to society, due to the lack of scientific knowledge. Some of these to be noted were: a lot of wasted effort in trying to convert the baser metals into gold; advanced scientific principles that prevailed in one section

⁴ *Memorie from Library of Congress; Papers of Columbian Institute*; printed by Gales and Seaton; 1817; pages cited, 2-29.

⁵ *Adams Memorie*, VII, 398.

⁶ Vol. VIII, 171.

were unknown elsewhere; trades had become encompassed in "too much mystery" rather than science. Machinery of complicated parts could never be useful unless there were trained mechanics to operate them. Scientific knowledge is a necessary pre-requisite for those employed in "making or using labor-saving machinery,—those who are to traverse the ocean, construct the canals, build steam engines, work our mines, conduct large agricultural experiments, or set up manufacturing establishments."

Looking to the immediate future, Mr. Everett declared that the older parts of the country which had been settled by the husbandmen and reclaimed from the state of nature, were now to be settled again by the manufacturer, the engineer and the mechanic. These sections had once been settled by the hard labor of human hands—now they will be settled by the labor-saving arts, by machinery, by the steam engine, and by internal improvements. All this would bring about significant social effects. Work in the Old World which had taken two thousand years to accomplish could be effected here in two hundred years. In those countries of the Old World, most of the prizes of life had been distributed by lottery of birth, whereas in America they were distributed on the basis of merit. An enlightened class of artisans, farmers and mechanics were the nation's best guarantee of its permanency. The perpetuation of such a social triumph would be cause for self-congratulation far beyond anything based upon mere material or political growth. "An intelligent class can scarce ever be vicious; never indolent."

Mr. Everett cautioned his listeners not to think that they were approaching the end of scientific experiments. On the contrary, they were only in the beginning stages. Art and science are progressive

⁷ Edward Everett, *Speeches and Orations*, 1836, Ed., Vol. I, 249.

⁸ *Ibid.*, 267.

—infinite in possibilities. "There is no end to truth, no bounds to its discovery and appreciation." His colleagues, fellow members of the Columbian Institute, were urged to join in this new undertaking of diffusing all useful knowledge among people everywhere. The elements of science should be imparted from kindred minds. The number of distinguished and useful men who are to benefit and adorn society are proportionate to the means and encouragement given to the useful inventions and discoveries. There had never been a time when greater improvements might be expected, provided inventors and scientists were given proper encouragement.

This paper of Edward Everett's is only one of several essays read before the various meetings of the Columbian Institute. But running throughout all the published addresses, there is one recurring note, namely, the time was at hand for putting science to work. This young nation would prosper only in proportion to the number of new and useful inventions. It was the duty of Congress to recognize this and give generous support.

But in spite of the efforts put forth by this little group of earnest men the Columbian Institute was never able to accomplish the things it set out to do. They had hoped, as Edward Everett had said, "to arouse the government to become the patron of the arts and sciences." And, although a few members persisted diligently in this aim, they never received much encouragement. Most of the members were too busy with other duties. Funds were not available for carrying on the work that needed to be done. The five dollars a year membership dues never amounted to more than \$300 at any one time. Congress was never convinced of the need for such an organization. As the years passed, the Institute took on more and more the character of a learned society

rather than an organization whose chief aim was "to promote the arts and sciences." Learned treatises were presented, but few practical projects were undertaken.

However, there were a few tangible results that came from this first attempt to unite the forces of science and the federal government. A valuable mineral collection was assembled, catalogued and, to this day, reposes in the Museum of the Smithsonian Institution. A real beginning was made in botanical and horticultural work. Rare specimens of trees, shrubs and plants were collected from all parts of the country and used for experimental purposes. Also, the Institute aided in the projects of the American Pharmacopeia Society, and in the establishment of the United States Naval Observatory. Then, too, the Institute assisted in organizing and conducting the Southern Pacific Expedition, 1838 to 1842. And finally, more than any other organization, it had kept alive an inter-

est in science throughout the decades of the 1820's and 1830's. By the time its charter expired in 1838, the new National Institute had been formed. The entire membership of the Columbian Institute was invited to join this embryo scientific group. This new organization in turn was soon to be succeeded by the Smithsonian Institution, now long distinguished as one of the world's most famous scientific societies. But due credit should be given to those who first pioneered in the field of applied science, and who launched this country into a study of its scientific and technological possibilities, rather than let it become a poor imitation of the literary and esthetic cultures of the Old World.⁹

⁹ Selected references are found in Richard Rathbun's *Report, U. S. National Museum Bull.*; No. 101, 1917; G. Browne Good, *Annual Report U. S. National Museum, 1890-1891*; *Annals of Congress*, Gales and Seaton; 14th Congress to the 22nd Cong.; John Quincy Adams' *Memoirs*; Edward Everett's *Speeches and Orations*, Vol. I; and files of *National Intelligencer*.

THE MEANING OF MORALE

IF it is to survive and at the same time be true to its own genius, democracy must reconcile enthusiasm with enlightenment, tolerance with conviction, strength with gentleness and unity with diversity. This problem of reconciliation is not artificial or gratuitous. It lies in the line of all genuine moral effort: to solve this problem is, in fact, morality itself. And there is a solution, hard though it be: to love the truth so much that one is hospitable to all its sources and channels, and respects the honest conviction of others; while at the same time loving humanity so much that one hates only inhumanity, and enjoys the equalities, the differences and even the rivalries which will spring from a wide sowing of the seeds of freedom. Men may be diverse in the lives they lead, and at the same time unified by a common love of their aggregate diversity. . . .

There is only one firm foundation for morale in a democracy, and that is to be, and not merely

to feel, democratic; to enact and not merely to talk democracy. To be a democracy, and we may as well be honest about it, implies a continuous redistribution of power and privilege in the direction of a greater participation by the masses of the people. It also implies that the people, enjoying a greater power and privilege, shall cease to be masses. In the present crisis the democracies represent not only this creed, which is peculiarly their own, but the whole Christian, humanistic and cultural tradition of the Western World. If the crisis is to be met with a high morale, Americans must learn to consider themselves the united servants of these great causes. But if they are to sustain this conviction they must *experience* democracy, Christianity and humanity as realities. The more grave the crisis the greater the necessity of *being*, of *continuing* to be and of *becoming* that which one professes to be.—Ralph Barton Perry, *The Educational Record*, July, 1941.

SCIENCE AND HUMAN VALUES

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HUMAN civilization is the cumulative product of man's age-old faith that the universe he inhabits is intelligible and rational. It embodies principles of unity and order that his mind can comprehend and his will can employ in adding to the comfort of his body and the delight of his soul. All the material and spiritual achievements of humanity bear testimony to the validity of this confidence. Whenever it fades, the human mind lapses into lethargy and the will into impotence. Civilizations collapse when it perishes, and are reborn when it revives.

But this faith was itself a slow and hard-won achievement. For the gift of intelligence did not come to man like the latest mechanical gadget, accompanied by detailed instructions for its use. For untold centuries he looked out upon the universe in awed wonder, with no method of exploring its nature but his groping curiosity. His conception of his world was consequently vague and confused, and his control over it wavering and uncertain. With no effective intellectual method of winnowing the true from the false, he made many mistakes, and his knowledge consisted of a few grains of fact buried amidst vast accumulations of error. Myths, legends, magical formulae, empirical rules of thumb, these were his only intellectual store. Yet for hundreds of thousands of years they sufficed for the development of the rudimentary economic techniques of hunting, fishing, herding, agriculture and industry, together with social and political organization, and even morality, religion and the fine arts. Only four or five thousand years ago, in ancient Egypt and Babylonia, did there appear the first intimations of those methods of critical thought

and investigation through which man was able at last to attain his vast intellectual achievements in philosophy and science. And therewith he acquired an increasing confidence in himself, and a growing faith that the world of nature constitutes, in part if not in whole, an intelligible order which his mind can comprehend and his will can command.

But for centuries after these first beginnings, man's methods of inquiry into the world about him were crude and bunglesome. Not until three hundred years ago can his most effective intellectual tools for investigating physical nature, the scientific method, be said to have been definitely constituted, and only since the dawn of the nineteenth century can they be said to have been intensively developed and employed.

Indeed, for a millenium and a half, from the collapse of the classical civilization of Greece until the dawn of the Italian Renaissance, the western world merely marked time in so far as the further development of scientific method was concerned. Men of the Middle Ages, however intellectually active they may have been in the fields of philosophy and theology, paid little attention to the scientific phase of the Greek tradition, and made no significant positive contribution to it. But the intellectual upheavals of the Renaissance and the technical problems created by the rise of capitalism and nationalism joined theory to practice, and wedded observation and experiment with imagination and reason into that harmonious union which provided the scientific movement with a new dynamic.

Into this new movement Francis Bacon threw himself with such vigor and

enthusiasm that he has often been called the father of inductive science. He was, however, rather its chief apostle, its leading interpreter and propagandist. The proper method of science, he said, is the wise interrogation of nature, and this consists in formulating problems so that they may be answered by a simple yes or no, and in devising experiments to produce the facts that constitute the answer. But for several generations the new method succeeded in imposing its program on astronomy and physics alone. Not until the close of the eighteenth century was it applied to chemistry, and not until the beginning of the nineteenth to biology. Finally, under the inspiration chiefly of John Stuart Mill in England and Auguste Comte in France, the idea became widespread that the methods which had won such notable successes in the study of the physical world might be applied to man and his institutions, to give him a control over human relations comparable to that already won over the physical and the physiological. The psychologist began to move out of the library of the philosopher into the laboratory of the scientist, and the economist, political scientist and lastly, the sociologist moved out of the study where they had previously sought to explain social conditions, and entered the world of practical affairs which they now sought to investigate and describe as first hand observers.

The scientific movement was accompanied by the greatest outburst of buoyancy and optimism that the human spirit had ever known. Bacon had insisted that the purpose of the new knowledge was exclusively to mitigate the sufferings and increase the happiness of mankind. And for nearly three centuries the triumphs of western civilization in mechanical invention, in medical improvement, in economic, political and social organization, seemed to prove him right. Populations increased, cities grew, wealth accumulated, death rates fell, the span of life lengthened, standards of living

rose, museums and art galleries were founded, schools and universities flourished. Forecasting the course of the future from the time of the French Revolution, Condorcet declared that "from the observation of the progress which the sciences and civilization have hitherto made . . . we shall find the strongest reasons to believe . . . that nature has fixed no limit to our hopes." Only the destruction of the earth itself can put an end to the infinite perfectibility of man and his institutions.¹ And throughout the century following, publicists and men of affairs, with now and then a rare exception, united in this hymn to progress. Herbert Spencer wrote:²

Progress therefore is not an accident, but a necessity. . . . The modifications mankind have undergone, and are still undergoing, result from a law underlying the whole organic creation. . . . As surely as the tree becomes bulky when it stands alone, and slender if one of a group; . . . so surely must the human faculties be molded into completeness for the social state; so surely must evil and immorality disappear; so surely must man become perfect.

In 1898 Alfred Russell Wallace described the hundred years just drawing to a close as "The Wonderful Century" and in 1919, F. S. Marvin referred to the period between the Napoleonic era and the close of the World War as "The Century of Hope." Even as late as 1920, Paul Haworth brought his study of the United States since the Civil War to a close with a chapter entitled "A Golden Age in History," while only twelve years ago, Herbert Hoover, in his campaign for the presidency, expressed his conviction that we are on our way to abolish poverty from the land, and to place two cars in every garage and two chickens in every pot.

Although it has long been apparent to thoughtful minds that science contains

¹ *Outlines of an Historical View of the Progress of the Human Mind*, p. 319, London: J. Johnson, 1795.

² "Social Statics," p. 80. New York: D. Appleton and Company, 1865.

little promise of fulfilling the hopes it had raised, it is only within the last decade that the common man has come fully to realize the extent to which his hopes have been betrayed. For the ultimate problems of our civilization are social and moral, and science, while it has placed new and powerful instruments in the hands of men, has done nothing to clarify the moral and social purposes which these instruments are to serve. Consequently the instruments, which in the hands of men of social intelligence and good will might have realized our hopes, are now being employed by the strongest and most ruthless to destroy them.

The betrayal of man's higher spiritual values by the machines he has himself created is nowhere more poignantly portrayed than in the motto of the British Broadcasting Company, "Nation shall speak peace to nation," promulgated in a world in which the radio has become man's most efficient instrument of speaking lies and war. It was the radio that laid down the barrage of propaganda that prepared the way for the ruthless aggression practiced upon China, Ethiopia, Spain, Albania, Austria, Czechoslovakia, Poland, Lithuania, Latvia, Estonia, Finland, Denmark, Norway, Luxembourg, Belgium and Holland. These sixteen peoples, nearly one fourth of all the independent nations of the world, have, within less than half a decade, passed under the yokes of conquerors made diabolically efficient by contributions of physics and chemistry to the arts of destruction. In the economic field science has enormously increased our capacity to produce, but it has also made our opportunity to consume more insecure. It has concentrated wealth and economic power into the hands of a few, driven a wedge between the farmer and his land, the craftsman and his tools, and made both dependent, not upon their own industry and thrift, but upon the vagaries of the market and the price system. Viewing the results in these two fields

alone, economics and international politics, what hope remains that applied science will promote the higher values of man's spirit?

To this indictment the scientist has two replies: first, that if the findings of science are bent to such nefarious ends, the responsibility does not rest upon the scientist, but upon the practical men of affairs, the statesmen, the politicians, the captains of industry and finance. But this is only to plead guilty to the charge of Launcelot Hogben. "The education of the scientist and technician," he says, "leaves them indifferent to the social consequences of their own activities." We may justly paraphrase a question raised by Charles and Mary Beard in another connection, Are they to regard themselves as the members of a privileged gild, entitled to go their own way without reference to the fate of society? Rare indeed among scientists is the social conscience of the Swedish chemist, Alfred Nobel, who shrank back in horror from the uses of human destruction to which his production of dynamite had been put, and who devoted a considerable part of his life and fortune to the promotion of international peace, that the product of his genius might not continue to wreak havoc with mankind. Equally rare among inventors is the social conscience of the Rust brothers, of Memphis, Tennessee, who have refused to sell their mechanical cotton picker, but only license it for use, in order that its commercialization may not bring idleness and starvation to millions of farm laborers of the South, and who plan to use their profits to create a fund to relocate in industry the workers whom their invention may displace.

The second reply of the scientist to the indictment that science has been destructive of the higher human values is that science as such is morally neutral. It has

"The Retreat from Reason," p. 3. London: Watts and Company, 1936.

"America in Midpassage," Vol. II, p. 869. New York: The Macmillan Company, 1939.

no concern with value. It is interested in quantities, not qualities. It studies only what is, not what ought to be. It can tell us only what is true, not what is right or good or wise or beautiful or holy. For knowledge of these things we should turn, not to the scientist, but to the philosopher.

Even the social scientists have of recent years made common cause with the natural scientists in washing their hands of all concern with human values. The economist, the political scientist, the sociologist, we are told, must study a social situation as the astronomer studies a nebula or the biologist an organism, to describe what exists, and to predict, if he can, what must exist to-morrow, but that is all. He may study suicide, divorce, crime, poverty, unemployment, strikes, lynchings, war, but whether these things are good or bad he does not know. Any interest in their ethical implications, or any concern about human welfare, is scientifically taboo. He is a social technician solely. He can teach us efficiency in attaining our ends, but not wisdom in choosing them. He tries to learn, for example, how depressions are caused and how they may be prevented, but whether we should have bigger and better depressions or smaller and fewer, is a question of social ethics or social welfare, and he does not know. Lest this appear to be caricature, let us note a recent statement of a former president of the American Sociological Society:

That there has been any recent, catastrophic breakdown in the social order is not immediately evident. There has been, to be sure, a marked increase in unemployment and economic distress: the percentage of the population that is unable to secure unassisted the minimum means necessary to continued existence is large and increasing. But this does not in any real sense represent a breakdown in the system; on the contrary it may equally well be taken as representing the culmination and flowering of the traditional social and economic order.⁵

⁵ Quoted from *Social Forces*, 13: 203, December, 1934.

Under the pressure of this trend in sociology at least, if not also in economics, political science and history, it is as much as a young man's academic future is worth to show an interest in the ethical or welfare aspects of social problems, and many an intelligent young graduate student is frightened away from research upon problems of the most pressing human concern for fear of the effect upon his future prospects of appointment and promotion.

We might for the present accept this defense of the scientist, that science is concerned with what is, not with what ought to be, and that for knowledge of human values we must turn not to him, but to the philosopher, if the scientist were in fact such a humble person as this answer implies. For it reduces the scientist to the role of a mere servant of the philosopher, providing the means whereby we can realize the human values which the philosopher validates and clarifies. But the scientist is rarely so self-effacing. He is usually quite convinced that scientific knowledge is alone entitled to respect, and, emerging from his laboratory, he thrusts aside the work of the philosophers as worthless, and proceeds to formulate a view of human life and destiny in harmony with his own professional bias. Thus, R. K. Duncan, a former professor of industrial chemistry in the University of Kansas, has written:

We believe—we must believe, in this day—that everything in God's universe of worlds and stars is made of atoms, in quantities x , y or z respectively. Men and women, mice and elephants, the red belts of Jupiter and the rings of Saturn are one and all but ever shifting, ever varying swarms of atoms. Every mechanical work of earth, air and water, every criminal act, every human deed of love and valor: what is it all, pray, but the relation of one swarm of atoms to another!...

Now, whether we call the atoms God's little servants or the devil's agents, one thing is sure—that every action of every thing, living or dead, within this bourne of time and space, is

the action of one swarm of atoms on another, for without them there is but empty void.⁶

Here we have it clearly and baldly put: our human values, our acts of love and valor, our aspiration for goodness and beauty, are one with the belts of Jupiter and the rings of Saturn, atoms dancing in an empty void!

In such a world, man's belief that his choices are in any sense real, that he can engage in creative activity of any kind or contribute towards the realization of his ideals, that by taking thought and expending effort he can in any significant way modify the course of events, develop his personality or conserve and enhance the world of values—all these are vain illusions. As Dr. John H. Bradley has expressed it:

The desire to get somewhere is deeply rooted in the human heart. Man wants ends for his struggles, hopes and fears, where he fancies he will find peace. But nature has an entirely different point of view. . . . She has imposed a cyclic pattern upon the universe, whereunder all things are charged to go on for ever, but never to arrive.⁷

In such a world man should never "waste time looking for a purpose where probably there is none," but "let it pass."⁸

Thus the scientific movement, beginning with the assertion that it has no concern with human values, often ends by heaping contempt upon philosophy, which has. For the natural scientist, working in his laboratory with the basic conceptions of matter and mechanism and quantity, is all too prone to think of the entire universe outside the laboratory in these terms, and to assert, as do the writers already quoted, that all reality is material reality, that all causation is mechanistic causation and that all

knowledge is quantitative knowledge. And, since the human values, truth, beauty, goodness, holiness, can not be weighed or measured, it follows that we can have no valid knowledge about them, and that they can be nothing more than illusions born of our desires. As Joseph Wood Krutch has expressed it, either the light of science is somehow deceptive, or all the things we cherish are unsubstantial, all the values we pursue and all the principles we cling to are but shadows, and the universe, emotionally and spiritually, is a vast emptiness.⁹

This shattering of confidence in spiritual values is the most damaging blow that science could strike mankind. It has centered attention upon the tangible and the ponderable, exalted material possessions as the measure of human worth, and substituted comfort, excitement and entertainment for truth, goodness and beauty, as the supreme values of life. This concern of modern man with material things has left a void in his soul, and, shut up between the darkness of the birth from which he came and the darkness of the grave to which he goes, he can only fill the void with an increasing volume of material possessions and an increasing intensity of sensuous satisfactions. It has made of life a system of tensions, a continuous succession of strains which is never followed by relaxation.

But these facts, disconcerting as they are, provide no basis for a fundamentalist tirade against science as such. The structure of modern science stands as the greatest achievement of man's intelligence; the technological inventions which it has made possible remain as the greatest accomplishment of his hands. But a science which assumes that its basic concepts of materialism and mechanism and quantity exhaust the possibilities of dependable knowledge has ceased to be science, and degenerated into a

⁶ Quoted from Max C. Otto, "Things and Ideals," p. 182 f. New York: Henry Holt and Company, 1924.

⁷ SCIENTIFIC MONTHLY, 30: 457, May, 1930.

⁸ C. C. Furnas, SCIENTIFIC MONTHLY, 31: 50, July, 1930.

⁹ Atlantic Monthly, 149: 162-72, February, 1927, and 151: 372, March, 1928.

dogma which has betrayed civilization. For if we can discover no dependable knowledge of the good life which the intelligence must recognize as valid and the will as obligatory, our civilization can not survive the forces which science has let loose within it. For unless the principles of moral and social obligation can be recognized as binding upon the impulses of every individual and the interests of every group because they are rationally valid, there remains no way of settling the conflicts that rage between individuals, economic classes, political parties, religious sects, nations and races, but by the appeal to force and violence. "Let them fight it out," say those who have lost their faith in the capacity of intelligence to discover rational principles of social order. But they have not been able to fight it out in ten thousand generations, though they have destroyed innumerable civilizations in the attempt. And they can not fight it out in ten thousand generations to come, though still more civilizations perish. For though a nation can by force set its house in order, it can not by force establish order within its house. And though a nation can by war force another nation into submission, it can not by war force another nation into harmony with itself. Order and harmony come by agreements mediated by reason, not by treaties imposed by arms. When interests are repressed by force, they remain as occasions for new conflict; only when they are adjudicated by reason are they set permanently at rest.

But never in the history of Western civilization has confidence in a moral order based upon reason been weaker; never have moral principles been more cynically flouted, never have fraud and falsehood been more brazenly flaunted, never has force been more ruthlessly wielded. Never could less reliance be placed in the solemn treaties of nations or the pledged word of statesmen. For what can we expect of a civilization

nourished intellectually on the bouillon cubes of science without the vitamins of value but that it should suffer from moral rickets?

One may, of course, be reminded of Malachi's despairing cry, ringing down twenty-five centuries of time from ancient Judea, "Why do we deal treacherously every man against his brother, profaning the covenant of our fathers?" He may be reminded, moreover, of Aristotle's cynical advice to the tyrant in the Fifth Book of his "Politics," of the political immoralism of Machiavelli's "Prince" or of Thomas Hobbes' observation that man is unto man a wolf, and that his natural state is a war of each against all. The answer to this is fourfold.

First, these are the laments of prophets and the observations of scholars, not the confessed policy of statesmen. Not until the rise of the contemporary dictators have the responsible heads of states while still in power publicly acknowledged their use of fraud and violence as regular instruments of political policy, as Mussolini, and especially Hitler, have done in their official publications.

Second, the areas of social life still under the sway of the ordinary human decencies have been so wide that heretofore the dictator has been compelled by public opinion at home and abroad strictly to follow Machiavelli's advice to his Prince that, though he need be neither honest nor generous nor just, he must always appear to be so.

Third, while it is true that deception and violence have always stood in the background of human affairs, they have most of the time remained there, to be brought into action only in moments of extraordinary crisis, but the modern dictators have made the crisis perpetual. Bismarck considered war the extension of diplomacy, but it has taken a Hitler to make diplomacy an extension of war.

Fourth, although deceit and cunning and violence have never been absent from

history, not until they became armed with the resources of modern science and technology could they on a scale so ruthless and colossal destroy all the human values which decent men prize. It is high time for all who call themselves scientists, whether physical or social, to make common cause with philosophy and the humanities in the defense of human values, and in the competence of scholarship and research to find a rational basis for them in human experience which all men must accept. For let there be no mistake about it, in the midst of the passionate social conflicts that rage about us, if scholarship and research are unable or unwilling to determine the ends of economics and politics by reason, economics and politics will determine the ends of scholarship and research by force.

Dictatorship is the legitimate fruit of our loss of faith in reason to discover dependable knowledge of human values. For if there are no universal principles of moral obligation which the minds of all men must recognize and the will of all men obey, one man's opinion of what is good and bad, right and just, is as valid as another's, and the only guides to human conduct that remain are the biological impulses of individuals and the vested interests of groups. But such an unrestrained conflict of impulses and interests must reduce the individual life to madness and the social life to chaos. So in the theory and program of nationalism the interests of the state have been made supreme over all other interests in conflict. When the interests of individuals and groups clash it is recognized that all lesser interests must yield to the common good. It is recognized that there can be stability and harmony within the state only in the proportion that principles of equity and justice are available to serve as a basis on which the conflict can be resolved, not by might, but by agreement. But nationalism recognizes no such general principles of the rational good, binding upon it in a conflict within the family

of nations. Here the nation becomes the final judge of its own interests; it is under no obligation to consider the consequences of its policies upon other nations, and as a last resort, there is no other alternative than the appeal to war. In that event, the highest moral obligation of the citizen is to die for his country, right or wrong.

But the dictator sees no grounds for applying one set of principles to conflicts between nations, and another to conflicts within them. If self-interest is supreme, and reason is degraded to serve the ends of expediency in the one case, it is equally so in the other. Neither within the nation nor without can the reason discover principles which the will is bound to respect. Consequently, the human values, truth, goodness, beauty, holiness, justice, honor, right, are what the self-interest of the dictatorship pronounces them to be. The minister in his pulpit, the editor at his desk, the teacher in his classroom, the philosopher in his study, the scientist in his laboratory, all alike must prove and proclaim whatever the dictatorship requires; they must disprove and denounce whatever the dictatorship commands. As the Nazi courts have recently decreed, if an official commits a punishable act out of religious or other social motives, "these motives will be regarded not as attenuating circumstances, but as proof that he is involved in relationships which he values more highly than those which connect him with his superiors and with the state."¹⁰

The tragedy is that the greatest single intellectual influence in establishing this rule of unreason has been the dogma of natural science, that the only rationally valid knowledge is knowledge of things in their material and quantitative relationships and that all alleged knowledge of human values is mere opinion, born of self-interest and desire. If science is to realize its earlier promise, and to con-

¹⁰ *Information Service*, p. 3. New York, April 20, 1940.

tribute to the enrichment of human experience and the mitigation of its ills, it must abandon this dogma and lend its influence to the re-establishment of confidence in the competence of the human mind to discover rational and intelligible principles of unity and order, not only in the realm of physical nature, but also in the realm of the human spirit.

The knowledge most desperately needed is knowledge concerning the principles of social organization and the ends of social action. No social science is adequate to this task that is descriptive only, that confines itself to exploring what is and predicting what will be. For human nature and human society are vastly richer and more complex in their potentialities than in their accomplishments. An adequate social science will of course begin with a careful collection of facts about how men carry on their common life together as families and communities, as economic classes and political parties and religious sects, as nations and races, but it will not stop there. It will pass on from this concrete knowledge of social actualities to the consideration of social possibilities. It will endeavor to work out all the logical possibilities of human association that rigorous analysis can disclose. It will formulate logically, in advance of the facts, the meaning and value which social life might contain if it were rationally ordered. If science is to contribute to human welfare, it must consider logical knowledge of the possibilities of social life as of equal importance with factual knowledge of its nature. For unless social policies are based upon fact they will not work; and unless they are grounded in logical principle they will not endure. A science which is adequate to our needs therefore will explore, both factually and logically, with a view to discovering both the actualities and possibilities of human existence, the five great fields of social relationships where

civilized man now stands frustrated and defeated.

It will explore, first, the relations of men to one another as persons, in the family, the community and other face-to-face groups, where the extent of their frustration and defeat is measured by the statistics of suicide, mental and nervous collapse, divorce, delinquency, criminality and general personal maladjustment.

It will explore, second, the relations of men to one another as producers, or the problems of economics, where the extent of their frustration and defeat is measured by the statistics of unemployment, poverty, bankruptcy, business failure and recurrent depressions.

It will explore, third, the relations of men to one another as citizens, or the problems of politics, where their frustration and defeat is measured in terms of political corruption, machine domination and the general failure of our democracy heretofore positively to promote the common welfare which the Constitution of the United States places high among the primary purposes of government as stated in its Preamble, instead of giving its chief attention to the incidental and secondary rights of property which in the Constitution itself are tucked away in the due process clause of the Fourteenth Amendment as a sort of afterthought.

It will explore, fourth, the relations of men to one another as organized states, where their frustration and defeat stand disclosed in international anarchy, in the dread that stalks the lands, the horror that rains from the sky, the terror that lurks in the sea and the fear that rides the ether.

It will explore, fifth, the relations of men to one another as biological varieties, or the problems of race, where the measure of their frustration and defeat is revealed in the obscenities and cruelties of race prejudice, in riots, lynchings, pogroms and concentration camps.

It is a grim task, but beyond it there lies a great hope, the hope that by means of a social science that has become intelligent enough to extend its scope from social facts to social values, from a consideration of what is, to what might be and ought to be, we may formulate a rationally valid conception of the general social welfare, and develop a social organization adequate to mediate between the conflicting interests of human groups.

This is an old hope. Ever since the Greek philosophers began to reflect about man's life and destiny, it has been the unwavering conviction of the clearest intellects and the choicest spirits that the human mind is a competent instrument in clarifying the ends of our existence, and the human will is an active agent in attaining them. If this hope be false, no civilization can endure, and there remains nothing out of the wrecks of time for which decent men should care to live.

But there is no reason to believe that the hope is false. It is often said that man is not a reasonable creature, but it may be remarked that if this is really so, only by reason can the fact be known. And reasoners who employ reason to prove the incompetence of reason are interesting objects of study. As Irwin Edman has said, "Reason may indeed become a fetish, but so may distrust of it."¹¹

But that a major part of our behavior wells up out of biological impulses or socially acquired interests of which we are unconscious or only dimly aware, constitutes a quite different problem. Here the daily experience of every civilized man bears witness to the competence of intelligence to produce harmony and order out of the clash of impulse and desire. Every day we bring the ends which we impulsively desire under the control of larger ends which we ration-

ally recognize as desirable. Every day in the common decencies of life we adjust the claims of our personal and group interests to the interests of other persons and groups freely and gladly, because we rationally recognize the allegiance we owe as human beings to a life that is wider than our own. But as individuals and groups forge their way to economic and political power the rational control of intelligence weakens, the sensitive sympathy of the heart withers and the ruthless energy of the will abounds. From the destruction which this ruthlessness is now wreaking in our contemporary life, there can be no doubt but that the continuance of our civilization depends upon our ability to make this conception of the general social welfare as the only rational good so clear and convincing to man's intellect that in these wider areas of life it will compel the allegiance of his will.

Can we accomplish this result before our civilization is destroyed by the conflicts that now rage within it? We can not tell. If the odds against it seem heavy, we must remember that it has always been so. Life has always been fraught with risk and adventure, and the future with uncertainty. But if our present efforts fail, it is not unlikely that the same human nature which has pressed on through the repeated failures of vanished civilizations will persevere through future ages until it reaches whatever success its own capacities, the resources of physical nature and the limits of time will permit. For within the processes of social development, from the dawn of man until now, there has been operating the irresistible human impulse to be, to know and to do.

Our thought, then, ends in neither complacent optimism nor enervating despair. The outcome is doubtful enough that none of us dares be laggard, but hopeful enough to challenge us to the task with zest and high courage.

¹¹ "Four Ways of Philosophy." New York: Henry Holt and Company, 1937.

SOME OBSCURE RELATIONS OF ORGANISM AND ENVIRONMENT

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It has been suggested that I write a "reply" to Professor Ely's article appearing in *THE SCIENTIFIC MONTHLY* for February, 1940. This seems to me inadvisable for two reasons. First, there is to-day a very extensive technical literature of psychical research of which any brief summary for the purposes of discussion would be futile. Second, most of Professor Ely's article actually consists of a useful account of pitfalls in the subject, especially in the attempt to obtain results with platform performers.

But, since what is needed is more and better experimental research, the familiarity of scientists with some of the existing work may aid in planning critical or more penetrating investigations which carry us beyond the points reached. My task then is to attempt a compact account of certain types of experimental research which have been undertaken in relation to the problem of extra-sensory perception, hoping that the reader will look up the original sources and go further. My aim is simply to show that there is a *problem* which requires full analysis. The solution of the problem will be achieved not by debate but by scientific research.¹

(1) In 1921, Dr. G. F. Heymans, renowned as an experimental psychologist at the University of Groningen in the Netherlands, undertook with two of his university colleagues, Drs. Brugmans

¹ For the same reason I can not separate telepathy from clairvoyance merely because the philosophical difficulties seem to some writers greater in one case than in the other. Most of the good research has been done on the two together or in comparison of the two under similar experimental conditions. It is not philosophical expectation, I think, but experimental unity of subject matter that determines what belongs together in science.

and Weinberg, an investigation of the ancient and annoying problem of telepathy. Doubting the appeal to logic and metaphysics, the three men wanted to find out whether, under their own laboratory controls, as strict as they could make them, such a thing as telepathy did occur. There was at hand a young student of dentistry, Mr. Van Dam, who had the habit of going into relaxed or passive or more or less trance-like states. Such states had often been said to be productive of telepathic results. Why not try and see if this was the case?

Accordingly they made available for an experiment two rooms of the university laboratory, one directly above the other. They cut a large hole down through the floor of the upper room and through the ceiling of the lower room, and inserted double plate glass, permitting an air cushion between the two rooms. For use in the lower room they constructed a black cage in which their subject could sit. Looking down through the glass, observers in the upper room could see no part of their subject's body except the forearm and hand thrust through a horizontal slit in the cage at the level of the waist of the subject seated within. The subject was blindfolded. The question was whether, by thinking about it, the experimenters in the upper room could in any way influence the subject's choice as to certain numbers chosen by lot in the room above.

On a table in front of the cage was a rectangular board, about 12×9 inches, marked off into 48 squares in an 8×6 arrangement. The subject knew that in each experiment his task was to tap with his finger upon the board so as to indicate

one of the 48 numbers. After every few trials, an experimenter came in to the lower room and slightly changed the position of the board on the table so as to break up position habits of the subject.

All three of the aforementioned members of the psychology department acted as experimenters, but not all three at once. They worked one at a time. The task of the experimenter at any given session was as follows: First making sure that the blindfolded subject was in his cage and that his arm was extended through the horizontal slit and outstretched toward the board, he was to draw cards by lot to determine for each experiment a number from 1 to 48 inclusive. He switched out the lights, went over to the glass partition, looked down through the hole at the subject's arm, and willed that he should move a finger to the designated number. In view of the possible danger that an experiment would be prematurely terminated when the subject accidentally touched the right number, the rule had been established that the subject must tap twice at a given point when he had made his decision. From the charts and photographs supplied in the publications, it appears that the distance from the glass window to the hand was about four and one-half feet.

The foregoing is the "two room" procedure. In another procedure, used half the time, the blindfolded subject and board were as before, but the experimenter entered the lower room and tried to will the movement of the finger while gazing at it at short range.

A total of 187 experiments were performed. The routine statistical procedure gives us 1 chance in 48 of success by random guessing, so that by chance 4 of the experiments should have been successes. Actually, 60 were successful. Those in the "two room" procedure were better (34 successes in 80, as against 2 expected) than those when the experimenters entered the lower room.

With reference to the magnitude of

errors, the data are instructive. The errors by 1-square displacement are commoner than those by 2-square displacement. These are commoner than those by 3-squares, so that there is a tapering off of guesses as the magnitude increases—almost a normal curve of errors around the correct hit as the central tendency.²

Most striking in this investigation are two lines of attack upon the physiology of the process. First, we said above that Mr. Van Dam had a tendency to go into relaxed states. The experimenters naturally wished to make use of such a condition in two ways, first to *augment* the relaxed states to study the effect, and second, to *measure* as precisely as possible how deep the relaxation really is. The first purpose was accomplished by giving 30 grams of alcohol. Out of 29 alcohol experiments, 22 were successes, interpreted as the action of alcohol usually is interpreted, in terms of "inhibition of an inhibition," reduction of tensions and the like. Second—and this was regarded as so important that it takes up almost the entire space on the long second report published by the Dutch investigators—the galvanometer was used to measure the electrical responses of the body. The galvanic skin reflex, or psycho-galvanic reflex, long known to experimental psychology, was put to use in a form characteristic of laboratory work and curves offered in the experimental report to substantiate the major generalization which runs as follows: The periods of greatest physiological passivity, which were found best in the telepathic experiment, can be detected objectively.

These investigations are published in the *Proceedings* of the First and Second

² Wishful behavior by which experimenters might count as hits those instances in which the tap was on the line between two squares might spuriously add here and there to the total, but even if this occurred in every trial in a chance series so as to allow all squares adjoining the right one to count as hits, the total would still be vastly below the reported total of hits.

International Congresses of Psychic Research held at Copenhagen and Warsaw respectively. They were read to these congresses by Dr. Brugmans. Subsequent correspondence shows that Mr. Van Dam turned to other things, "lost interest," and "lost his power," ceased to score significantly, and that the investigators, having nothing more to add and nothing to retract, decided to let the case stand as it was. So far as I can ascertain, nothing more on the subject by this method has been published by any one.

(2) Believing that uniformity in the material to be used through various experiments is important for many reasons, especially for quantitative comparison of one long series with another, J. B. Rhine, of Duke University, initiated in 1930 and to-day continues work with the five standard symbols, circle, rectangle, star, cross and waves. These may be printed on cards, shuffled, cut and concealed. When large masses of material are at hand, standard statistical procedures can be applied to the resulting distributions of correspondences between the subject's report (call series) and the actuality ("target series"); and control series can be obtained by independently shuffled and cut decks as well as by machine preparation of material. The cards are usually screened, often removed to a distance. Their order may be at the time unknown to any one, the stack of cards lying on a table or in a box; or the distant experimenter may gaze at each card as he comes to it, proceeding downwards through the deck. Different methods, different sizes of stimulus symbols, etc., and different subjects may be compared.

One of the central problems was the effect of distance. Accordingly one of the regular subjects, Mr. Pearce, went over to a room in the Duke University Library while the experimenter, J. G. Pratt, established himself with a deck of the cards in the Physics Building 150 yards away, in a room facing away

from the Library.³ He shuffled the cards face down, then cut them and put them in a face-down stack on a book. Pearce proceeded to call the cards "down through," from top to bottom, series after series. His record, and Pratt's record, were independently submitted to Rhine, scored and photostated. The hits, by runs of 25, are as follows: 3, 8, 5, 9, 10; 12, 11; 12, 11, 13, 12. The expected number (by chance), is 5; a score of 12 or better should occur about once in 700 runs.⁴ The odds against such a result of random sampling (chance) are in the billions. A second such series was run under the same conditions but with the experimenter and cards 250 yards away in the Duke Medical Building, and the scoring level was again such that an experimenter should not expect to see it in a lifetime.

In all, four such long distance series with Pearce were done, as shown in Table I; each may be compared with the "same room" condition (Group E).

TABLE I

Group	Conditions	Number of trials	Average
A	Physics building and library	300	9.9
B	Medical building and library	1100	6.7
C	Physics building and library	300	7.2
D	Physics building and library	150	9.3
E	Same room	900	8.2

A good deal has been written about the possibility of recording errors which might increase the number of hits. I went through the above in the photostats and found one error. It was the omission of a hit.

(3) In 1935, Rhine was asked to lecture on his current investigations before a faculty and student group at Hunter

³ J. B. Rhine, "Extra-Sensory Perception," 1934; cf. also, *Jour. Parapsychology*, 1: 74-76.

⁴ There is a slight sigma correction which may at times be useful because of "linkage"; it can under certain unusual conditions raise the sigma from 2.00 to 2.04; it can not appreciably affect high critical ratios.

College in New York. He gave a brief account of his methods and results. At the close of his report, a member of the faculty, Professor Bernard F. Riess, remarked, in effect, "Either you didn't use the methods you described or you didn't obtain the results which you report." Rhine smiled and remarked, "In other words, I'm a liar." Riess replied, "I didn't say that." Rhine said, "The only way in which you will reach any convictions regarding my own work will be through your own independent repetition of such experiments." Riess took the challenge. A student in one of his classes reported that she had a friend in White Plains who could "do this sort of thing," i.e., get impressions of concealed material. Accordingly, after a very considerable amount of trouble, arrangements were made for a long series of experiments to be done each evening at 9 o'clock, the subject being at her home in White Plains, Dr. Riess at his home a quarter of a mile away, on the other side of a hill. After shuffling a standard deck of 25 E.S.P. cards, Riess began at 9 o'clock looking at the card which was on top, and, proceeding at the rate of one per minute. Turning over each card when ready for the next, he proceeded through a deck of 25, immediately following with another 25 so as to give 50 one-minute trials for the evening. From time to time the subject sent in reports of impressions recorded in this experiment. These were placed in Riess's desk and nothing whatever was reported to the subject. At the end of 1850 trials, the subject had to terminate the series.

The relation of theoretical to empirical distributions with E.S.P. cards under control conditions, e.g., matching one deck against another, is so close that it is sufficient to say that a score more than 4-Sigma above mean chance expectation is exceedingly rare. I have, for example, never seen such a score in a large block of control data in the course of years of work on this problem. The actual dis-

tribution of hits made by Riess's subject is given in Table II. Since mean chance expectation is 5 and Sigma is 2, a score more than 4-Sigma up would be above 13, i.e., it would be 14 or better. The reader will see that the subject maintained a very much better score than this, hitting the 18's, 19's and 20's with almost monotonous frequency.⁵

TABLE II

Run	Hits	Run	Hits	Run	Hits	Run	Hits
1	5	21	21	41	16	61	18
2	7	22	20	42	21	62	18
3	10	23	19	43	22	63	19
4	12	24	20	44	17	64	18
5	15	25	18	45	16	65	17
6	8	26	14	46	18	66	18
7	16	27	15	47	19	67	19
8	13	28	15	48	21	68	20
9	18	29	16	49	20	69	20
10	21	30	12	50	19	70	20
11	11	31	19	51	16	71	19
12	15	32	21	52	21	72	20
13	19	33	22	53	23	73	21
14	24	34	24	54	19	74	21
15	21	35	20	55	17		
16	21	36	18	56	22		
17	22	37	22	57	21		
18	24	38	21	58	18		
19	25	39	19	59	16		
20	24	40	19	60	14		

Much has been written about the non-chance order of the "calls," or guesses, made by a subject. This is a very pertinent issue. Calls arise from a multitude of psychological factors in the organism, and are of course not a random series. The problem, however, is not the statistics of the call series; it is whether the order in the series of calls agrees consistently and repeatedly with the order of shuffled and cut decks at a distance (the "target"); the correspondence of the two is the very thing requiring investigation. In this experiment the subject made use of the five symbols with approximately equal frequency.

After a period of ill health the subject was persuaded to try another short series of 250 trials; she scored at the chance level. Merging the two series, while not according to ordinary scientific procedure since the conditions were different, would leave the chance problem unaf-

⁵ The Riess reports appear in the *Jour. of Parapsychology*, 1937, I: 260 ff., 1939, III: 79 ff.

fects. A single score of 22 or more would not be expected in continuous work through a century.

There are two kinds of comments which I have often heard on the Riess experiment. One relates to the possibility of recording errors. As far as I know, no one but Mr. Taves and myself has actually checked through Riess's original call and target sheets. In the course of 1850 calls we found one error. The other question has to do with Dr. Riess's veracity. This was the very question which was raised by Dr. Riess himself with reference to Rhine's report, and has for 50 years been repeatedly raised. I am aware that sooner or later the same will be said about me, because our own work has also given results which we can neither explain nor "explain away." To prove any one's veracity is to resort to further testimony which is also suspect, so that we are quickly involved in an infinite regressus. Science does not waste time on pseudo-legal problems of this sort; the discussion is sterile. If such experiments can in time be repeated with constantly improving procedures until ultimately every critic is satisfied and until the conditions governing the phenomena are clear, well and good. Till then, they may seem unused blocks, foreign bodies in the tissues of science, which can neither be used nor ejected. The future research will decide what they are.

(4) Effort in recent years has been directed to developing a simple fool-proof procedure not requiring the use of long distance but excluding all possibility of sensory cues or rational inference as to probable card orders, and reducing accidental errors in recording to the lowest possible minimum. Though the question of fraud on the part of experimenters can never be settled with mathematical certainty, the difficulty can be partially resolved by arranging that at least two experimenters independently record the data, lock them up, and require a third

party to check them. This combination of experimental safeguards has recently been developed at Duke, and is exemplified in a report by J. G. Pratt and J. L. Woodruff in the December, 1939, issue of the *Journal of Parapsychology*. The subjects, tested one at a time, sat on one side of the experimental table separated from experimenter and cards by a vertical screen. Fastened to the back of the screen, i.e., away from the subject, were five "key cards," of the five denominations already mentioned. At the end of the table away from the subject was the experimenter, who shuffled and cut a standard deck of 25 cards, holding them face down beneath another, inclined screen. It was then the task of the subject to poke with a pointer at one or another of five positions beneath the edge of the vertical screen, thus instructing the experimenter where to place the card which at the moment was at the top of the deck. The subject was by this procedure to *match* the top card with the key card which was fastened above the indicated position on the back of the screen; the performance was motor, not sensory. The correspondences, if shuffling is adequate, may be treated by the ordinary mathematics of the binomial, and if the shuffling is not ideal randomization, there should still be only chance relations between call orders and "target" orders except in so far as a causal principle, a behavioral linkage of calls and stimuli, is present. The key cards were obtained afresh by further shuffling and cutting for each experiment, being supplied by another experimenter and not shown to the experimenter who handled the cards during the experiment. The hits were counted and recorded independently by the two experimenters after each run of 25, the records being placed in a box for each experimenter and later checked by a third person. The number of discrepancies between the two experimenters in the course of 2400 runs of 25 each was 3; where the origin of an error was

unknown the lower of the two scores was used.

Thirty-two subjects took part in the procedure just described, with results yielding 489 hits beyond expectation. The chi-square method gives a p value of .000078 (random sampling would yield as high a deviation seventy-eight times in the course of a million experiments). A cross-check or *empirical control*, comparing call orders against other target orders than the one actually aimed at gave a result within ordinary limits for random sampling.

The main purposes of the experiment just described were to test the effects of size of stimuli and to test the effects of *habituation* to a given set of material. Within the limits set by four sizes varying from $\frac{1}{8}$ inch to $2\frac{1}{4}$ inches, size made no significant difference. Habituation effects, however, were marked. Average hits on the first occasion on which a given size of material was used were 5.39 per run; for second and third runs slightly less; thereafter not significantly deviating from the expected 5.00 (such habituation effects are an old story, but not previously so carefully examined). The point is stressed only because the question is often very reasonably asked: "Why go on repeating these studies unless your experiment serves to disentangle the significant variables, working toward the ultimate laboratory control of the phenomenon?" It is just such control that most contemporary studies aim to achieve.⁶

Space has limited this paper to a con-

⁶ A question that is constantly asked is this, "Where else besides Duke have positive results been obtained?" I hesitate to answer it because giving a list of universities may convey to some readers the sense of an "argument from authority," and this is out of place in science. Good work may be done in a bad university, bad work in a good university. Least of all should I want the reader to conclude that the individual university "vouches for" a result, any more than I should myself "vouch for" a result of any sort from any laboratory.

sideration of four experiments. All the data of each such experiment have, however, been included. There are many more experiments to be found in the literature. But the issue is not a question of "piling up" data. It is a question of determining by further and ever better work a system of functional relations between certain classes of objects and the perceptual and motor responses to them. As in other phases of science there is no place for gaping at mysteries or exorcising unexplained data.

The reader who is interested to follow the subject might first consult the original sources cited here; then run through the *Journal of Parapsychology* since 1937; then read J. L. Kennedy's "Methodological Review of Extra-Sensory Perception,"⁷ then read the elaborate survey of experimental data and critical discussion in the recent volume by Rhine, Pratt, Stuart, Smith and Greenwood, "Extra-Sensory Perception After Sixty Years."

One word about names. The title of this article was chosen so as to be non-committal as to ultimate interpretations. There are various names for these unexplained types of data. Emphasizing the relations of organism to stimulus, one may use the term *perception*. *Perception* is an "interpretation of a stimulus situation"; the interpretation is "correct" when there is a functional correspondence between socially accepted names for objects and the names given by the observer. When the receptor processes of the organism bear no known relation to the perceptual process, a purely operational definition, "extra-sensory perception," may be used. It is a neutral term, involving no hypothesis. There are, to be sure, hypotheses now proving serviceable in the guidance of research, of which a few have been suggested, but this article can not undertake to recount them more fully.

⁷ *Psychol. Bull.*, 36: 59 ff.

THE SCIENCE OF CORNELIUS DREBBLE

By Dr. GOLDWIN SMITH

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In the first decades of the seventeenth century Francis Bacon challenged a closed body of doctrine by asking a question. Few men in the preceding three hundred years had dared to oppose the standards of Aristotle. In a series of unexpected attacks, Bacon smote the scholastics hip and thigh, divided their ranks, drove them over the hills. During the century that followed the schoolmen made creditable but forlorn attempts to repair the disaster wrought by Bacon's appeal to induction. Through the years they were forced to continue reluctant withdrawal before new forces. At the end of the century Isaac Newton presented the world with an exact demonstration that the universe is one harmonious machine. Between the twin achievements of Bacon and Newton lamps of aspiration had been lit in innumerable laboratories. The Royal Society had been founded. Boyle and Harvey gave courage and elation to an England seeking a place in the newly robust circle of European science.

The course of the new science was undoubtedly aided by the work of a number of men, none of them in the first rank of scientists, who contributed their unspectacular mites to the brave crusade. They accepted and defended the formulae of emphatic protest against obscurantism. They helped to create a new "climate of opinion," sceptical and derisive, corroding the ancient fetters of authority.

One of these was Cornelius Drebbel. In some respects he was to make polluted contributions to the science of his age; in others he was to prove himself a consummate fraud. Yet he did pour scorn on the intellectual detritus of the preceding ages. His critical spirit was

sharp; his inventive genius was continuous. For a generation he marched behind Bacon and some, at least, of Bacon's precepts he made his own.

The early life of Drebbel is hidden beyond the mists of three centuries. There is evidence that he was a student of the famous Goltzius, master engraver of Alkmaer. It is probable that he executed an engraving of the city of Alkmaer in 1597, a work that appeared in a book published in 1747 by the Dutch historian Boomkamp. However this may be, Drebbel soon sought a wider arena for the exercise of his inexhaustible energy and curiosity. In 1608 he published a little volume, "On the Nature of the Elements." Here he discussed the manner in which the elements "cause the wind, the rain, the lightning and the thunder." In the Peiresc collection there is an anonymous French translation in manuscript. In 1621 Peter Lauremberg published a Latin translation at Hamburg. A German translation appeared in 1624 at Erfurt and two later Latin editions were produced in 1628 at Geneva and Frankfurt.

Most widely quoted of all the references to the early activities of Drebbel is the curious *Kronijcke von Alcmaer*, published in 1645 by Cornelis van der Woude. There it is recorded that Drebbel was tutor to the young prince of Austria and later counselor to Ferdinand II. When Prague fell in 1620 to the armies of Frederick of Bohemia Drebbel was said to have been taken prisoner, released as a result of Dutch and English intercession, called by golden persuasion to the court of James I of England.

At least a part of this biography we must dismiss as fiction. As early as

1609 Drebbel was established in England at Eltham Park, far from the board of Ferdinand. From the young Prince Henry he received gifts of value of £40 during the year 1610. From the king himself it seems likely that he received permission to use an apartment at Eltham. Here the exile from Alkmaar succeeded by his ingenuity in making his name known to most of London. His age was of course an age of credulity, and the state of physical science was crude. These facts help to explain the emergence of Drebbel as an alchemist, magician, empiric, professor of the black art. By observation, experience, mechanical skill and arrant knavery Drebbel persuaded large groups of the public that new truths could be brought to light by those who followed the star of the new scientific principles. To some Drebbel became a "deservedly famous mechanician and chymist"; to others he remained a charlatan.

It will be readily imagined that at a time when the foundations of scientific belief were becoming fluid, when a new scale of values was being insinuated into the teachings of the learned, when society was losing the firm grasp upon knowledge built by the great schoolmen the occasions for the impressive demonstrations of Cornelius Drebbel were numerous and inviting. They were particularly inviting to one of a genial and energetic temperament who could easily lay foundations of friendship and who sought a position of influence and authority.

The first, and certainly to contemporaries the most impressive, of all the devices of Drebbel appeared in 1609. He presented to James I a perpetual motion machine. A contemporary describes it as "a glass or crystal globe, wherein Drebbel blew or made a perpetual motion by the power of the four elements." In methodical obscurity he continues:

For everything which by the force of the elements passes in a year on the surface of the earth could be seen to pass in this cylindrical wonder in the shorter lapse of twenty-four hours. Thus were marked by it all years, months, days, hours; the course of the sun, moon, planets and stars. It made you understand what cold is, what the cause of the *primum mobile*, what the first principle of the sun, how it moves; the firmament, all stars, the moon, the sea, the surface of the earth, what occasions the ebb flow, thunder, lightning, rain, wind, and how things wax and multiply.

Then ensued the consequence that Drebbel had probably foreseen. To view this wonder at Eltham came people of all classes. The Prince of Wirtemberg made a special journey to gaze upon the creation of Cornelius Drebbel and to leave his royal words of admiration. Ben Jonson alluded to the popular interest when he caused Morose to exclaim in "The Silent Woman," "My very house turns round with the tumult! I dwell in a windmill! The Perpetual Motion is here, and not at Eltham!"

The strange machine that moved continually "without the help either of springs or weights" attracted also the attention of the Englishmen of science. Thomas Tymme published in 1612 a "dialogue philosophicall wherein nature's secret closet is opened." In his preface Tymme sets before his readers "A most strange and wittie invention of another Archimedes which concerneth Artificial Perpetual Motion immitating Nature by a lively patterne of the instrumente itself, as it was presented to the King's most royal hands." Tymme believed that in some fashion Drebbel had "extracted a fiery spirit" (or perhaps "scintillula animæ magneticæ mundi") and thus maintained the motion of the machine. In 1628 good Bishop Wilkins called the Eltham device "a chymicall experiment" and there permitted the problem to rest.

It must have been disconcerting to Cornelius Drebbel to discover that the popular appeal of his invention was not easily translated into money. But such

appear to be the facts of the case, for we find a petition addressed by Drebbles to Prince Henry in May, 1612. In this petition Drebbles declares that the Lord Mayor has refused him permission to hold a lottery. He pleads that he has no other means of subsistence and begs the influence of Prince Henry with Lord Treasurer Salisbury for leave to have a lottery beyond the jurisdiction of the city. He also sends a petition to Salisbury, explaining the proposed conditions for his lottery.

In the course of a few years, however, the fortunes of Drebbles seem somehow to have become more firmly established. He has meanwhile invented a mysterious automatic musical instrument. He has also made famous a scarlet dye. In his own age tradesmen throughout Europe reaped large profits from its sale. Later Drebbles was to give the secret dye formula to his son-in-law John Kuffeler and in the next generation it is known as "Kuffeler's colour," as readers of Evelyn will be aware.

There was another triumph which served to enhance the rising fame of Drebbles. For the Prince of Orange he invented portable iron ovens, an event of importance in the development of mobile army units. To these real achievements he added others, some of them more questionable. Soon he reached the apex of his renown. His name was magic. A contemporary writer, reflecting upon the bewildering genius of Drebbles, found no cause for litotes.

Aided by some instruments of his own manufacture, Drebbles could make it rain, lighten and thunder at every time of the year, so that you would have sworn it came in a natural way from heaven.

By means of other instruments he could, in the midst of summer, so much refrigerate the atmosphere of certain places, that you would have thought yourself in the very midst of winter. This experiment he did once on His Majesty's request, in the great hall of Westminster; and although a hot summer day had been chosen by the King it became so cold in

the Hall that James and his followers took to their heels in hasty flight.

With a certain instrument he could draw an incredible amount of water out of a well or river.

He made instruments by means of which were seen pictures and portraits; for instance, he could show you kings, princes, nobles, although residing at that moment in foreign countries.

He invented all these and many other curiosities too long to relate, without the aid of the black art; by natural philosophy alone, if we may believe the *tongues* of those whose *eyes* saw it.

There can be little question that Drebbles was prepared on occasion to pass the discoveries of others off as his own. All his contemporaries recognized some excellent qualities in the Dutchman, but they declared that it was the pith of good sense to suspect him of the worst. For instance, the famous "lunettes de Drebbels" were not his sole creation, even though they bore his name and attracted wide attention throughout Europe. Gassendi, Holstensius and Peiresc conducted a long correspondence upon the subject of the "lunettes" and to Gassendi Peiresc wrote "Et quand on voit du sable dans les lunettes de Drebbels, on y trouve aultant de façon et de perfection bien souvent qu'aux caillous entiers, et aultres pierres plus precieuses et diaphanes." Yet Drebbles, whom Gassendi called "ocellus eruditorum," was not responsible for the excellence that impressed Peiresc. There is also the fact that in 1619 Drebbles displayed a new microscope to William Boreel, the Dutch Ambassador. Drebbles described it as his latest invention. It had really been presented to him some months before as a gift from the Archduke Albert.

People liked to hear about the miscellaneous claims and inventions of this impressive scientist. They were well disposed to him, for the whole tendency was slowly beginning to flow strongly in the direction of that which was new, and that which was revolutionary therefore became that which was important. It was consequently to be expected that this man who had offered such a confi-

doubt ascertament of mechanical devices should have found the invention of a submarine particularly popular. And of his submarine "tryal was made in the Thames with admired success, the vessel carrying twelve rowers besides passengers."

A second contemporary continues:

He built a ship, in which one could row and navigate under water, from Westminster to Greenwich, a distance of two Dutch miles; even five or six miles, as far as one pleased. In this boat a person could see under the surface of the water, and without candlelight as much as he needed to read in the Bible or any other book.

Robert Boyle was deeply concerned in the search for an explanation of the secrets of Drebbel's submarine. In his "New Experiments Physico-Mechanicall" he attempts to answer the modern problem of oxygen supply.

Besides the mechanical contrivance of his vessel Drebbel had a chymicall liquor which he accounted the chief secret of his submarine navigation. For when he perceived that the finer and purer part of the Air was consumed or over-clogged by the respiration and steames of those that went in his ship, he would, by unstopping a vessell full of this liquor, speedily restore to the troubled air such a proportion of vitall parts as would make it againe for a while good for respiration, whether by dissipating or precipitating the grosser exhalations or by some other intelligible way I must not stay to examine.

The success which attended the launching of the submarine marked the last appearance of Drebbel as an idol of the populace. We possess, indeed, but fragmentary knowledge of the last decade of his life. We know that "Cornelius Drebbel the Engineer" marched in the funeral procession of James I. We know that he labored for Charles I to produce "divers water-engines." We know that he was paid £150 a month as an officer of three fireships (to be used against the island of Rhé).

It is probable that one of his inventions remained a secret. John Kuffler

and John Drebbel approach the government in 1662 to sell a secret of the great Cornelius. They request "a trial of their father Cornelius Drebbel's secret of sinking or destroying ships in a moment, and if it succeed, for a reward of £10,000. The secret was left them by will to preserve for the English Crown before any other state." Allusion to this petition is to be found in Pepys and Evelyn as well as in the Calendar of State Papers. There is no record of the final decision of the government.

In 1634 Cornelius Drebbel died in London. He was sixty-two years of age.

Great as were the sensations caused by the works of Cornelius Drebbel the fact remains that he was not a giant in the annals of seventeenth century science. What he achieved has been largely forgotten. His meager share of fame has been a pruned paragraph in the history of scientific progress. And yet he has a title to the hesitant applause of the moderns, and this article is in part a baptism of approval. For Cornelius Drebbel is an excellent symbol of a new age. He was one of the unsung disciples of Bacon and Harvey and Boyle. By slow degrees it was men like Drebbel who spread abroad the notion that science was not a matter to be left to the schoolmen who had been first in the field. No longer should superstition flourish like fungus under the scaffold.

Cornelius Drebbel may have been often a charlatan, frequently dishonest, but he hated passionately those who denied the precious principles of the new age and bowed before the authority of the fathers, with their "letters of opinion on tablets of lead." He denounced the impotence and scientific sterility of the scholastics. He believed with Bacon that truth was not the daughter of authority but a secret slowly to be retrieved from the womb of time.

BOOKS ON SCIENCE FOR LAYMEN

AMONG IGLOOS AND ICEBERGS¹

CONSCIOUSNESS of the frozen realm which lies to the north of us our readers have acquired through the books by Peter Freuchen, his "Eskimo," "Arctic Adventure" and "It's All Adventure," all of which appeared in the early thirties. The new decade has seen the appearance of Sydney R. Montague's "I Lived with the Eskimos," de Ponceins' "Kabloona" (Eskimo for White Man) and Carlson's "Greenland Lies North." All these have been built upon some years of experience in association with the stone-age primitives that are the inhabitants of the cold and barren realm to the north of us, where life is fearfully hard and gaunt famine stalks through every winter.

The scene of Carlson's book is, like that of Freuchen's, Greenland, which is now in the public eye as our new outpost toward the Nazi world. De Ponceins' narrative, like that of Montague, has to do with the Arctic fringe of British America, which is even less accessible and still less touched by civilizing influences.

Carlson went to the Arctic as a member of the scientific expeditions sent out from the University of Michigan, and for a full year he was in independent charge of an Arctic station north of 74° North Latitude. There he established himself with one white companion and with an Eskimo family as helpers and from which he carried out sledging expeditions with other groups of natives. He acquired their language and submitted to the unpleasant and unsanitary conditions incident to their hard life.

Through Carlson's book one learns of

¹ *Kabloona, A White Man Alone among the Eskimos*. Gontran de Ponceins, in collaboration with Lewis Galantière. Illustrated. xii + 339 pp. \$3.00. 1941. Reynal and Hitchcock.

Greenland Lies North. William S. Carlson. Illustrated. 306 pp. \$3.00. 1940. Macmillan Company.

the almost unique physical conditions of this great northern island of Greenland, as well as of the interesting racial peculiarities of its human denizens. It is a tale of adventure which is full of interest as well as instruction.

"Kabloona" takes us to an extremely remote island of the Arctic Archipelago, King William Land, near the North Magnetic Pole. Strangely enough, the reader is nowhere told of the tragic history connected with this island, though it surpasses all other places in the North, for it was in King William Land that perished the 125 men of the expedition of Sir John Franklin, to rescue whom no less than forty separate Arctic expeditions were sent out before the facts were finally cleared up.

Gontran de Ponceins is a French viscount who for fifteen months buried himself in this Arctic solitude, living most of the time in the igloos or on winter sledge journeys with some of the most primitive people on this earth. He had become disgusted with the life of his class and decided to become a wanderer in an attempt to find people who lived on better terms with their neighbors than those he knew best. As a result of this resolve, of his scientific training and of his facile use of the English language, he has put before us in this book the most illuminating study by one racial mentality of another. Even Freuchen, in spite of his two decades and more of association with Eskimos, has not given us so clear a revelation. As de Ponceins himself has put it, "A good part of this book . . . is the story of the encounter of two mentalities, and of the gradual substitution of the Eskimo mentality for the European mentality within myself." A very crude and primitive type of sketch wholly in character the writer has used to illustrate his book, an outstanding contribution to anthropology.

WILLIAM H. HOBBS

CAMOUFLAGE AND BLUFFING IN THE ANIMAL WORLD¹

COTT's book is far more than a beautifully illustrated treatise on the colors and color-patterns of animals, though it is that among other things. It is an important contribution to theoretical biology, particularly as this relates to the origin of adaptations. The anti-Darwinian reaction of a generation ago, with its all-but denial of adaptation as a product of natural selection, has largely spent itself. To the surviving representatives of this school Cott's recent volume offers a serious challenge.

The author of this volume has exceptional qualifications for his task, being a naturalist with wide field experience in various parts of the world, a scientific photographer and a talented draftsman. I trust that I am not betraying a military secret if I add that Dr. Cott's special knowledge of the principles of camouflage have been utilized by the R. A. F. in the present war.

The title of this book is somewhat too restricted, in view of its contents. Many other means of protection are discussed besides visual ones, as for example such peculiar defensive mechanisms as those of the skunk, the porcupine and the rattlesnake. Likewise, much space is devoted to the highly appropriate behavior of both cryptically and warningly colored animals, without which their color schemes would be largely futile. Our author, let us note, is as fully committed to the reality of warning ("aposematic") coloration as he is to that of the concealing type.

Cott's analysis of the principles employed by nature to effect concealment obviously owes much to Abbott Thayer, of some of whose ideas he makes extensive use. Thus vertebrate animals are commonly "countershaded," being most heavily pigmented on the more brightly

illuminated upper surface, and much less pigmented below. Many animals, too, are "disruptively" marked, so as to obliterate their contours and to destroy the apparent continuity of their body surfaces. Needless to say, Cott entertains no such obsession as did Thayer respecting the universality of concealing coloration in the animal kingdom.

Among other principles of concealment discussed by our author are the elimination of shadows, in cases where these would bring an animal into relief, and conversely the pigmental imitation of shadows, in some cases where such markings tend toward disguising an animal's true shape. One of the most surprising of all the methods in nature's bag of tricks is a class of phenomena which Cott has termed "coincident disruptive coloration." Here we have patterns which "run out of all relation to, and frequently cut right across, the distribution of deeper structures. Frequently, as we have seen, they bridge the gulf between upper and lower jaws; or step over the pupil from one side of the iris to the other; or cross the slit of the eye from lid to lid; or span the space between the folded segments of the leg." Nature seems to have in view the visible appearance of these pigmental patterns, entirely regardless of underlying morphological considerations. Such "coincident" patterns are well illustrated in a number of the author's fine figures, and indeed it is likely that many readers have already been aware of the existence of these decidedly puzzling patterns, without having speculated on their meaning.

While it is possible that Cott has adopted too unreservedly an adaptive interpretation for some of these phenomena of animal coloration—particularly ones of the "warning" and "bluffing" type—he has assembled a mass of facts and arguments which are, on the whole, convincing with respect to his main thesis.

In the days of Darwin, and of the

¹ *Adaptive Coloration in Animals*. Hugh B. Cott. xxii + 508 pp. \$8.50. 1940. Oxford University Press.

earlier writings of Poulton, it was possible to challenge the natural selection interpretation of these phenomena on the ground that it was unsupported by evidence. At the present time, however, there is a very considerable array of evidence, both observational and experimental, bearing on this subject. It is one of Cott's valuable services that he has assembled much of this evidence in his recent volume. This relates not only to the now generally admitted survival value of concealing coloration, but to the more debatable value of "warning" coloration. The importance of both of these principles as factors in evolution seems at present to be reasonably well established. No denial of this claim can henceforth command respectful attention unless it commences with a refutation of such evidence as has been marshalled by Dr. Cott.

The reader (or at least this reader) would have been saved considerable time and patience had the page numbers of the plates in the volume been indicated in the frequent references to them throughout the text. It is necessary to mention, too, one regrettable omission on the part of the author, which we can not regard as deliberate. This is his failure to mention that his figure 18 on page 67 is a free-hand copy of an ingenious colored plate of Thayer's ("Concealing Coloration in the Animal Kingdom," Plate XI).

Despite occasional grounds for minor criticism, Cott's volume is a highly important and very interesting contribution to the literature of animal ecology and evolution.

FRANCIS B. SUMNER

THE STORY OF PLAGUES¹

THIS is a first-class book. It is a combination of detective story, historical romance and scientific treatise. The stories it tells are of tragedies, mass

¹ *Plague on Us*. Geddes Smith. Illustrated. 265 pp. \$3.00. 1941. Commonwealth Fund.

deaths and the unraveling of the causative factors of diseases that have damaged and destroyed men for many ages. It wipes away the mists of superstition, clears up the clouds of fixed ideas or prejudices, and lets the reader see what has been done, how it has been done, and what will be done in the future if our studies are as fruitful in the future as they have been in the past.

Over and over again, as I turned the pages, photographs that I saw in Mukden of some of its alleys taken in that city in the early morning during the epidemic of some years ago of the pneumonic form of bubonic plague, came again into my vision. Scores of nude bodies, their clothing stolen by beggars, lay as they had been left to be picked up by the authorities. How often in the walled cities and garrison towns have human beings perished in the same way from diseases that were favored by herd living. Those who read "Plague on Us" will understand why public health should be supported and medical research encouraged. The human body as a reservoir of punishing organisms, the relationships of other living things to that body, and the way man and his society are winning in this struggle of one kind of life against another, are presented in a brilliant and sound manner.

I hope that Geddes Smith's book will become a "best seller."

RAY LYMAN WILBUR

MEDICINE THROUGH THE AGES¹

THIS book consists of six lectures by as many authors, each a graduate in medicine. One lecture sets forth the position of psychiatry (mental disease) in modern medical practice; the other five are historical—the origin of some common ideas about health; health advice in Elizabethan England, and medical and surgical practices of that time;

¹ *The March of Medicine*. New York Academy of Medicine Lectures to the Laity. xii + 154 pp. \$2.00. 1940. Columbia University Press.

ideas and practices current in Colonial America; the story of surgery and the story of insanity.

Dr. Walter C. Alvarez, of the Mayo Clinic, physiologist and clinician, finds in savage society the germs of origin both of scientific medicine and of quackery. Massage, bone setting and the giving of herbs, practices of the savage, were among the scientific ancestors of modern medicine; while the quackery of to-day is the lineal descendant of the primitive witch doctor's "control" of the spirits.

The wisdom of the first has been corrected and amplified down the ages. The second was born of ignorance, but has survived into our age of enlightenment as a cynical play on the credulity of the sick. The contrast drawn by the author is clear and entertaining. It will not be misunderstood as attributing to the practitioners in savage society the same separation of identity, of knowledge and ignorance, and of worthy and unworthy motives that exists to-day between the trained practitioner of medicine and his untrained or unscrupulous counterpart.

Dr. Sanford V. Larkey, historian, Johns Hopkins University, and Dr. Cecil K. Drinker, physiologist, Harvard University, picture the beginnings of modern medicine in England and Colonial America, respectively. Elizabethan England saw the beginning of health books of the family medical adviser type. It is interesting that these were more given to rules of prevention than to cure.

The charlatan was a recognized menace, and the licensing of qualified physicians was begun in this period to protect the public against him. The Dean of St. Paul's was given the responsibility of questioning the would-be practitioner to determine his fitness. Later the "companies" or "colleges" of physicians and surgeons took over the responsibility. In a day of beginnings, the barber could at the same time be dentist and surgeon; and the apothecary and the grocer were in the same guild. Blood letting, purg-

ing and baths were popular measures for treatment.

This was the day of the great plagues, and these stimulated the development of public health regulations by the state. Among the earliest were laws to protect the water supply, to keep the streets clean, and laws for the improvement of housing conditions.

The account of Colonial America by Dr. Drinker is based on the diary of Elizabeth Drinker, housewife. It covers 49 years, from 1758 to 1807. The extracts from the diary as quoted by the author are full of amusing incidents and reflect the keen sense of humor of Mistress Drinker. There is an account of the establishment of the first board of health in Philadelphia (in 1799); of a law forbidding slaughtering of cattle in the streets (1721); of the establishment of public bath houses in Philadelphia (1771); of the installation of a backyard shower at the Drinker home (1798); an account of an all-over bath, taken at great risk of health; of the cleaning out of a backyard "necessary"; of a nearby mineral well of great if temporary virtue. It was the province of midwives to care for women in childbirth, and a woman who employed a physician, a "man-midwife," was considered immodest. One new-born child out of three died.

Dr. Charles Gordon Heyd, surgeon, New York City, traces the development of modern surgery as essentially the history of the control of hemorrhage, of pain and of infection. Tying of bleeding vessels was known before the time of the Greeks, and was rediscovered by Ambroise Paré (1510-1590), son of a barber-surgeon. Blood letting was used three thousand years ago in treatment of "obsession with demons." It was a common treatment for a variety of ills, into the early years of the nineteenth century. Blood letting was early practiced by the monks, then after 1163 became the prerogative of barber-surgeons.

In the history of the control of pain the author tells of the discovery of ether anesthesia by Dr. Morton, and in the control of infection in surgery, refers to Dr. Oliver Wendell Holmes's deduction (1843) that the infection of puerperal sepsis is carried by dirty hands, the similar view of Semmelweis, Lister's experiments with antiseptic sprays (1867) and Halsted's introduction of rubber gloves. Other high lights in the history of surgery are given.

Dr. R. G. Hoskins, physiologist, director of research, The Memorial Foundation for Neuro-Endocrine Research, writes the history of insanity. Primitive man ascribed to events in nature motives similar to those that moved him, and inevitably, it seems, developed a belief in a spirit world. Dreams were an important factor, as here the dead walked again among the living. In line with such beliefs, the earliest explanation of insanity was that the sick person was possessed of an evil spirit. The earliest treatment was the incantations of the witch doctor.

Hippocrates repudiated the supernatural explanation of mental and other disease (460-475 B.C.) and classified mental diseases in a way that seems almost modern, but with the overthrow of Grecian culture by the Romans, the former concept regained its original authority. It was accepted in New Testament scripture and continued to be held during the middle ages by the Church Fathers, and by "the Phi Beta Kappas of the time." Even leaders as late as Calvin, Luther and Wesley continued to hold this view.

In accordance with this belief, treatment of the insane in the middle ages included the use of holy water, visits to holy places, fasting and prayer. Herbs, magic stones and incantations were recommended. The belief that beating and reviling the patient was equally punishing to the demon within led to use even of torture as treatment, and insanity came to be identified for all practical

purposes with sin. "Bedlam" Hospital (St. Marys Hospital of Bethlehem) for the insane was one of the show sights of London.

The author traces the history of the more humane and rational treatment of to-day. In his account appear as pioneers of reform, Saint Dymphna of Gheel, Philippe Pinel (1745-1826), William Tuke and, in America, Benjamin Rush and Dorothea Lynde Dix.

Dr. Karl A. Menninger, psychiatrist and author, writes an entertaining and convincing plea for psychiatry, the "Cinderella of Medicine." He emphasizes the interdependence of mind and body in the sick patient, and urges that the physician recognize psychological and social factors in his everyday practice.

Although addressed to the general public, the book should be equally interesting to the medical practitioner.

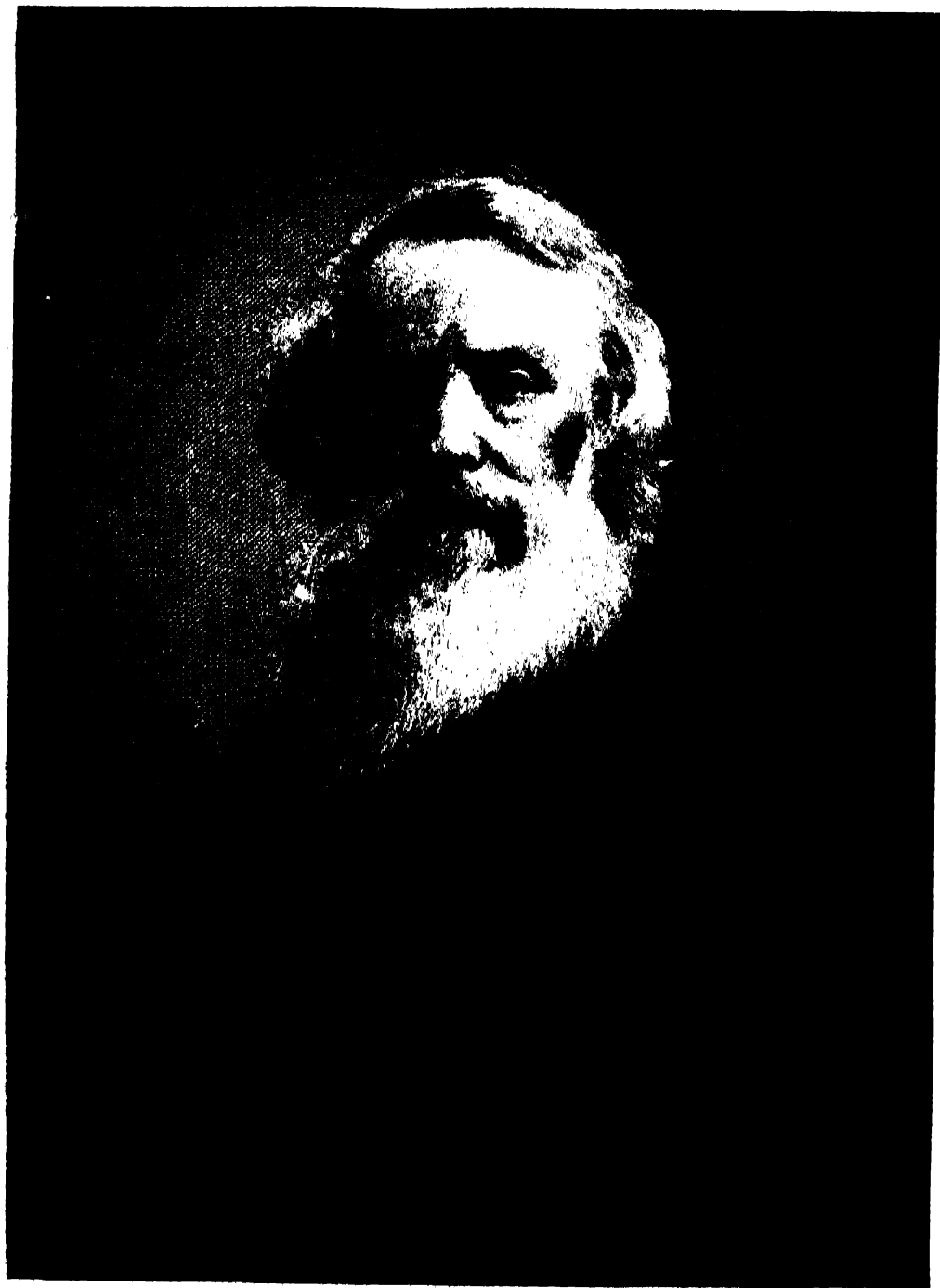
ERRETT C. ALBRITTON

THE DISCOVERY OF MAN¹

THE subtitle states that the treatise is "The Story of the Inquiry into Human Origins," but we read later that it is "a tale which traces the growth of the twin sciences of archeology and anthropology from their beginnings among the Greeks to the present day," by a reader in classical archeology at the Oxford University. In reality the book is a very creditable historical presentation of the main facts relating to man's prehistory. Its six sections deal with: The beginnings of anthropological inquiries and observations among the Old Greeks; The decline of interest in the field; New worlds to search; The age of reason; Great discoveries, and Modern advances. American matters are not gone into with any great detail, but are dealt with sensibly, even as to the present Folsom illusion. The whole book is, moreover, very readable and deserves to be recommended to the public.

A. H.

¹ *The Discovery of Man*. Stanley Casson. Illustrated. vi+399 pp. \$3.00. 1939. Harper and Brothers.



Sam. F. B. Morse.

THE PROGRESS OF SCIENCE

SAMUEL F. B. MORSE, 1791-1872

SAMUEL F. B. MORSE and Michael Faraday were born in the same year, 1791, one hundred and fifty years ago. Faraday was born in London¹ and Morse in Charlestown, Mass. Both spent most of their lives in the study of electricity and electromagnetism, Faraday on investigations of the fundamental relations between them and Morse on the invention and perfection of wire telegraphy. One was the scientist; the other, the inventor.

The early surroundings of Morse were much more fortunate (if our ideas of what is a favorable environment for youth are sound) than those of Faraday. Morse attended Yale University, from which he graduated in 1810. He had the privilege of studying under Jeremiah Day and Benjamin Silliman, the latter the founder and for many years the editor of the *American Journal of Science*. He did not show, however, any exceptional taste for science during his student days. Indeed, he was more interested in art, and in the year following his graduation he went to England to study art. He was one of the founders and the first president of the National Academy of Design, which was organized in 1825.

Morse gradually became interested in electricity and in 1832 definitely set himself to the task of developing wire telegraphy. In the first year he made rough drawings of a method of accomplishing the desired results. After making his own models, moulds and castings, he completed his apparatus in 1836 and gave the first exhibition of its working on September 2, 1837.

The way of the inventor has often been hard. In 1837 Morse petitioned Congress for an appropriation to test his

apparatus on a commercial scale and to demonstrate its value. He obtained his first patent in 1840, but no aid was forthcoming. Finally, in 1843, Congress passed an appropriation for a telegraph line from Baltimore to Washington, which was put into use on May 24, 1847. The first message was, "What hath God wrought!" In the meantime he had applied for a patent in England and had been refused. France granted him a patent but later expropriated it for its own use without compensation to the inventor. In 1858 several European governments, including those of Austria, Belgium, France, Netherlands and Russia, made monetary appropriations to Morse, who then took up experiments on submarine cables.

Many predecessors of Morse approached the idea of an electric telegraph, but did not follow it through with the construction of workable apparatus and the invention of a code. Among the better known scientists who saw, at least dimly, the possibilities of sending messages over long distances by electricity were Roger Bacon, Franklin, Newton, Ampère and Joseph Henry. Morse developed a system that functioned and, indeed, one that would carry two independent messages over a wire at the same time.

Fortunately for America the telegraph and steam railroads were both invented at the time the tide of western migration began to flow strongly across the Mississippi Valley, the Plains States and on to the Pacific Coast. These inventions made this rapid mass movement possible, and the mass movement made the rapid expansion of railroads and the telegraph necessary. The first continental telegraph line was completed in 1861. With the driving of a golden spike in 1869 the continent was first spanned by a railroad.

¹ See the August issue of THE SCIENTIFIC MONTHLY, page 183.

The development of both the railroads and the telegraph facilities has been phenomenal. To take care of the messages that are now sent from and received by more than 50,000 telegraph offices and agency stations nearly two and one half million miles of copper wire is required, exclusive of ocean cables. Much more would be required if it were not now possible to send several messages over the wire at the same time and with much greater speed than by the dot-dash-space method invented by Morse.

There are interesting and important human aspects to every scientific development. The telegraph has reduced the

loneliness of the frontier and carried many happy messages as well as those that were sad. It gives employment to about 65,000 persons, all except the officers working only 40 hours a week. It provides opportunities for investment to more than 30,000 persons, the average investment being approximately \$1,000 and none exceeding 2 per cent. of the stock of the largest telegraph company. It pays ten million dollars in taxes. It is an essential element in the infinitely complex and incomprehensible machinery of our present life. Samuel F. B. Morse! Rest in peace!

F. R. M.

THE UNIVERSITY OF CHICAGO CELEBRATION

For the first time since its organization ninety-three years ago the American Association for the Advancement of Science will hold two summer meetings in one year. The first meeting this summer was held at Durham, N. H., in June in connection with the celebration of the seventy-fifth anniversary of the founding of the University of New Hampshire. The second will be held from September 22 to September 27, inclusive, at Chicago in connection with the celebration of the fiftieth anniversary of the founding of The University of Chicago.

Most of the programs at Chicago were organized by The University of Chicago under the general title "Fiftieth Anniversary Symposia." In addition to the symposia there will be thirteen general sessions at which distinguished scholars will deliver addresses in the fields in which they have achieved eminence. It is expected that they will be given honorary degrees by the university.

Thirty symposia under the general title "New Frontiers in Education and Research" will be presented during the week of the celebration and two will be held at earlier dates. The University of Wisconsin will join with the University of Chicago in a symposium on "The

Respiratory Enzymes and the Biological Actions of Vitamins," the first part of which will be held at Madison on Thursday-Saturday, September 11-13, and the second part at Chicago on Monday-Wednesday, September 15-17. The other symposium to be presented in advance of the celebration week is "The Training of Biologists," which will be held on Thursday-Saturday, September 18-20.

On the first day the chemists will begin with a two-day symposium on "Organic Chemistry," the biologists will hold one on "Growth and Differentiation in Plants," and the biologists and the medical scientists will start their discussion of "Problems in Aerobiology." The social scientists start their series of programs by a symposium on "The Public Social Services: Fifty Years of Progress"; the linguists, with "Approaches to Linguistics" and "The Editing of a Text"; and the educationists, with "Environment and Education." The programs are so extensive that, in order to finish in the week, in most fields they begin on the first day.

Perhaps the most extensive symposium is that on "Levels of Integration in Biological and Social Systems," a subject



BERNARD A. ECKHART HALL

WHICH HOUSES THE DEPARTMENT OF MATHEMATICS AND PART OF THE DEPARTMENT OF PHYSICS.



LEON MANDEL HALL OF THE UNIVERSITY OF CHICAGO
THE GENERAL ASSEMBLY HALL CONTAINING THE AUDITORIUM.

that was discussed by Dr. Ralph W. Gerard in the April, May and June, 1940, issues of *THE SCIENTIFIC MONTHLY*, which will be presented on Tuesday and Wednesday. Eleven scientists from five institutions will participate in this program.

Of all the subjects discussed, probably none has given rise to more varied opinions than "Cosmic Rays." It is highly appropriate that this subject should be considered at Chicago, for Dr. Robert A. Millikan, formerly a professor in the University of Chicago, is one of the earliest and foremost investigators of cosmic rays; and Dr. Arthur H. Compton, chairman of the Department of Physics in the university, is equally eminent in the field. Although these two distinguished Nobel Prize winners agree largely on the observational evidence they have quite different interpretations of what it may mean. Perhaps this sub-

ject illustrates as well as any other the general title of the series of symposia, "New Frontiers in Education and Research."

A symposium on a very timely subject is that on "Life at High Altitudes and Aviation Medicine." Although war has many terrible features, such as the destruction of life, the impairment of health and the more tragic dissolution of the finest human qualities, it has some good results. During the First World War much was learned about wounds, shock and malnutrition. During this war much human physiology is being learned because many aviators must fly at great heights. The observations and experiments are not made in airplanes but in airtight chambers in which atmospheric pressure can be lowered as required. Another interesting subject related in part to high altitudes is the transmission of low forms of life, both

plant and animal, by air for long distances. This question is a part of that discussed in the symposium on "Problems in Aerobiology."

Naturally the future of society is the subject of grave consideration. Its va-

rious aspects will be discussed in such symposia as "Civilizations in Transition," "The Place of Law in Society," and "The Place of Ethics in Social Science."

F. R. MOULTON

HISTORY SECTION OF THE SMITHSONIAN INSTITUTION'S NEW INDEX EXHIBIT

THE History Section of the Smithsonian Institution's new index exhibit comprises three wall recess panels labeled "civil history," "naval history" and "military history." In each recess a carefully selected series of objects exemplifies one of these three leading branches of the science of history as developed in a museum.

The central feature of the civil history recess is a bronze copy of Houdon's portrait bust of George Washington, flanked by a china plate and a silver tray, both owned at Mount Vernon by General and Mrs. Washington during the last years of the eighteenth century. In front of the bust is shown the small portable mahogany writing desk used by Thomas Jefferson when writing the first draft of the Declaration of Independence. Other objects to illustrate civil history are a silver teapot made by Paul Revere, another owned by Samuel Chase, a signer of the Declaration of Independence, and a series of United States coins and medals.

In the recess devoted to naval history an oil painting made in 1864 of the *U. S. S. Hartford* may be contrasted with an actual model of a First World War submarine chaser. A naval officer's sword and scabbard of the early part of the nineteenth century, naval medals of the War of 1812 and naval decorations of the First World War complete the naval history exhibit.

In the center of the military history recess is an oil painting showing the 77th Division marching down Fifth Avenue, New York, in 1918. Changes in styles of

military headgear are illustrated by an enlisted man's cap of the period of the War with Mexico and a steel helmet of First World War days. Examples of Revolutionary War military medals and military decorations of the period of the First World War are also shown.

Across the top of the three recesses hang a series of nine small oil paintings representing the arrangement of the stars in the union of the United States flag at various times during the period 1777-1940.

The exhibit as a whole serves to represent the Historical Collections of the Smithsonian Institution, which are used not only for public exhibition but also for serious historical research. Those collections include also various other types of museum materials illustrating the lives and times of American historical characters and the material circumstances of the periods during which they lived. The emphasis placed on objects of a naval and military character in the present exhibit is in harmony with the spirit of the time and indicates the relative importance of the rôle played by materials of this character in the collections as a whole.

The historical collections brought together at the Smithsonian illustrate in an excellent manner the interrelationship between the civil, naval and military phases of American history and indicate clearly the rôles played by many eminent Americans in one or more of these fields of national service. Many mementoes of the careers of notable figures in American history both as soldiers and as states-



THE BUST OF GEORGE WASHINGTON FORMS THE CENTRAL THEME OF THE EXHIBIT DEVOTED TO CIVIL HISTORY OF THE UNITED STATES.



DECORATIONS, SWORDS AND SHIPS ILLUSTRATE PERIODS IN THE HISTORY OF THE UNITED STATES NAVY IN THE NAVAL EXHIBIT.

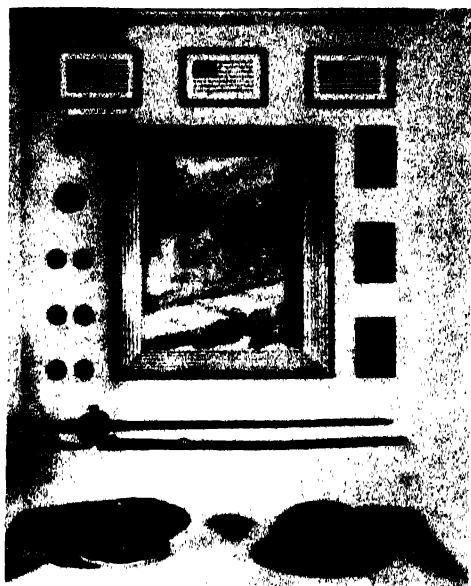


THE HISTORY ALCOVE OF THE SMITHSONIAN INDEX EXHIBITS

men are included. The mementoes drawn from civil history represent the normal development of American civilization. The naval and military collections depict the development of the national energy in these two fields in times of national emergency in accordance with democratic processes and under the general direction of the civil authorities, as contrasted with that of the professional militarist.

Of the many types of media useful for the expression of these three phases of history in museum form, those of special importance in the field of civil history are such materials as china, glass, silverware, furniture, costumes, paintings, engravings, coins and medals; in the fields of naval and military history, arms, flags, uniforms, insignia, decorations, ship models and various types of naval and military paraphernalia.

THEODORE T. BELOTE



RELICS OF THREE WARS
THE REVOLUTIONARY, MEXICAN AND FIRST WORLD
WARS MAKE UP THE MILITARY EXHIBIT.

NINTH SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS

THE Ninth Summer Conference on Spectroscopy and Its Applications was held at the Massachusetts Institute of Technology on July 21 to 23, inclusive. An indication of the current interest in spectrographic analysis of materials and in other applications of the spectrograph to scientific problems was the fact that advance reservations were made for all available seats. Attendance at the conference was limited to 250, it being desired to preserve the air of informality which has been found so conducive to animated discussions at previous conferences. A number of Canadian spectrographers were in attendance, as well as representatives from the Hawaiian Islands and other distant points.

It is difficult to point to any definite trend in spectrographic analysis as evidenced by the thirty papers presented at the conference. Steady progress is noted

in the application of spectrographic methods to various problems of biology, chemistry, metallurgy and physics.

Among the papers which excited the greatest interest were those dealing with the development of new equipment. Professor O. S. Duffendack, of the University of Michigan, discussed the use of Geiger-Mueller counters in spectroscopy. A new spectrograph for the ultra-violet region was discussed by Dr. S. Jacobsohn, of the Gaertner Scientific Company, and an instrument for the infra-red was described by W. H. Avery, of the Shell Oil Company. Drs. H. B. Vincent and R. A. Sawyer, of the University of Michigan, described a new type of microphotometer for measuring line densities on the photographic plates used in analytical work. Several manufacturers of spectrographic equipment had new apparatus on display, and were

invited to describe this during the regular sessions, provided they were willing to receive open discussion and frank criticism from the floor.

Significant improvements in methods of spectrographic analysis were discussed by Dr. W. F. Meggers, of the National Bureau of Standards; by Dr. M. Slavin, of the U. S. Bureau of Mines; by Harry W. Dietert and Carl King, of the Harry W. Dietert Company; and by Drs. Sawyer and Vincent.

Of particular interest to metallurgists were papers on the spectrochemical analysis of tin by B. F. Scribner, of the National Bureau of Standards; of aluminum by H. V. and J. R. Churchill, of the Aluminum Company of America; of tellurium by R. E. Nusbaum and J. W. Hackett, of the Research Laboratories of the General Motors Corporation, and of lead, cadmium and zinc, in dust fumes and ores by H. I. Oshry, J. W. Ballard and H. H. Schrenk, of the U. S. Bureau of Mines.

Particular applications of spectrographic methods were discussed by A. E. Ruehle, of the Bell Telephone Laboratories, who spoke on spectrochemical applications to vacuum tube research; by C. W. Rankin, of the New York State Police, who spoke on applications of the spectrograph to toxicological investigations; and by Daniel Norman and W. W. A. Johnson, of the New England Spectrochemical Laboratories, who discussed the spectrographic analysis of meteorites.

Of special interest to biologists and physicists were the sessions on absorption spectroscopy. Professor W. R. Brode, of Ohio State University, dis-

cussed a new automatic recorder of absorption spectra and rotatory dispersion. Another absorption spectrophotometer was described by A. O. Beckman and H. H. Cary, of the National Technical Laboratories. Dr. D. DuBois, of the Yale University School of Medicine, described a new absorption apparatus for the study of rapid chemical reactions. The absorption spectra of various complex organic compounds were discussed by Dr. H. H. Darby, of Columbia University, and Dr. Peter A. Cole, of the U. S. Public Health Service. Dr. Darby and Professor M. G. Mellon, of Purdue University, led discussions on terminologies to be used in new analytical methods involving the spectrograph.

Other papers dealt with film and plate processing equipment and with methods to be used in handling photographic plates for spectrographic analysis. Contributions to this part of the discussion were made by Dr. Jacob Sherman, of the U. S. Navy Yard at Philadelphia, and by Dr. L. W. Strock, of the Simon Baruch Research Institute at Saratoga Springs.

Basic discussions of the physical principles underlying spectrographic analysis were given by Dr. W. F. Meggers, of the National Bureau of Standards, and by Dr. Henry Hemmendinger, of the Massachusetts Institute of Technology.

The conference was enlivened by numerous discussions and interchanges from the floor, a circumstance which probably contributed to the extraordinarily low population of the corridors during the three days of sessions.

G. R. HARRISON

A PRIMEVAL LABORATORY IN PENN'S WOODS

THE U. S. Forest Service has set aside 4,131 acres of essentially virgin hemlock-beech forest, located on the Allegheny National Forest in northwestern Pennsylvania, to be devoted permanently to

scientific use and for the education and enjoyment of the public. This area is located on the northern Allegheny Plateau 7 miles south of the town of Ludlow, and is unique in containing the largest acre-



ANCIENT HEMLOCK INTERSPERSED WITH SMALL BEECH TREES

age of original forest of its type in the East. It is also the largest single remaining body of virgin timber between the Adirondacks of New York State and the Great Smokies of North Carolina. The purchase and reservation of this tract, which was advocated by leading scientists and vigorously promoted by the Pennsylvania Forestry Association, had the support of the late Chief Forester, F. A. Silcox, and was approved by the National Forest Reservation Commission in 1934. Its reservation is an important forward step in the U. S. Forest Service program of permanently preserving natural areas characteristic of native forest and range vegetation in all regions of the United States.

In administering this area the Forest Service recognizes two obligations. First, to preserve the native animal and plant life in their natural state, in so far as this can be done on an area of this size; and second, to stimulate use of the area

by competent scientists, naturalists and the lay public to study, enjoy and record the life that goes on in undisturbed northern hardwood forests. To open up this area by motor roads and to provide elaborate facilities for picnicking or camping, thereby encouraging its use as a park, would obviously create disturbances that would profoundly affect both plants and animals. That unavoidable disturbance may be at a minimum; the motor road will terminate at the northern border, where foot trails will lead through choice stands of virgin timber and past points of scenic interest. These trails will be confined to the northern half that is designated as the Tionesta Scenic Area. Here the inspiration and true recreation to be found in a fairly large area of primeval forest may be enjoyed amid towering hemlock 300 to 500 years old and veteran beech 350 years of age. The southern portion, consisting of 2,113 acres and designated as

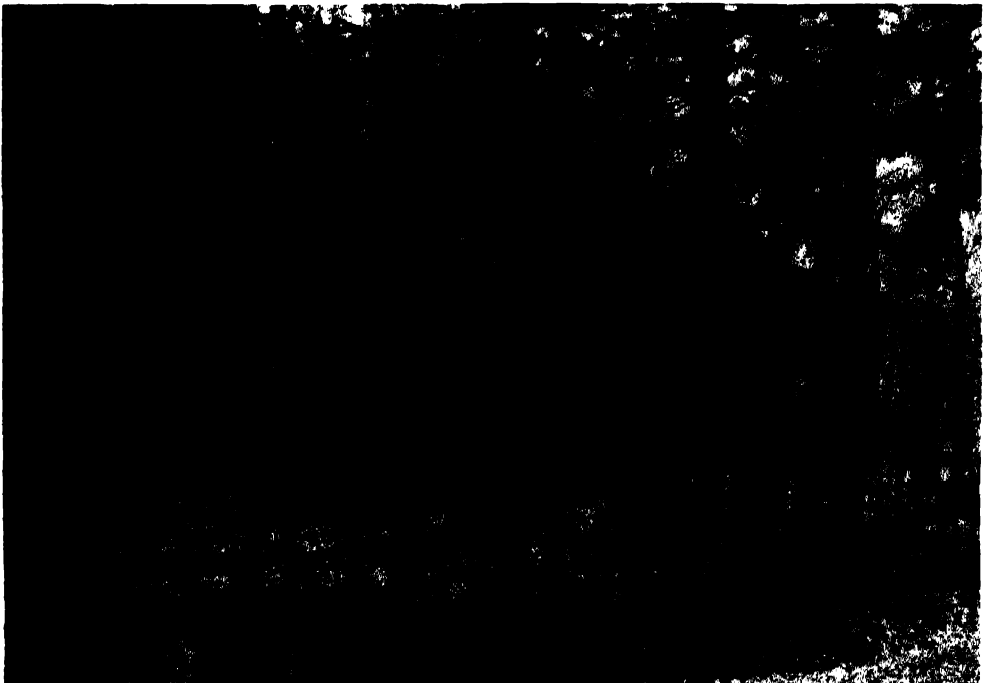
the Tionesta Natural Area, is dedicated primarily to scientific research and will remain without developed trails.

This tract as a whole has been essentially undisturbed by the activities of man for 500 years, though there has been some oil and gas development within the last 50 years. Contrary to the usual concept, a virgin forest is not static but is responsive to natural forces which tend to tear it down and build it up. During periods of stress, caused primarily by severe droughts, many mature trees die, and greater or smaller openings are created in the forest canopy. Preservation of this area makes possible studying the response of the forest to such catastrophes as drought, windthrow, fire and glaze storms, and observing the way in which natural regeneration takes place after these destructive agents have eliminated the veteran trees.

The species composition of a virgin forest indicates those most likely to per-

sist and succeed under local soil and climate and most suitable for selective cutting for continuous forest production. Likewise the virgin forest in which some species of trees are all-aged and others in even-aged groups suggests the system of forest management which may be used in each case. The number of trees per acre and their quality in original forests also give important keys to the productivity of forest soils and to methods of stand improvement applicable to our second-growth forests. Portions of the virgin forest undergoing cycles of mortality followed by rejuvenation are excellent indicators of ways to secure natural regrowth following man-made harvest cuttings in mature forests.

The Tionesta Natural and Scenic areas possess an interesting animal population of large and small mammals, such as bear, whitetail deer, porcupine, raccoon, bobcat, beaver, muskrat, mink, weasel and snow-shoe hare. Common among



HEMLOCK, BEECH AND YELLOW BIRCH ON LOWER SLOPE OF FORK RUN



A LARGE BEECH TREE
MEASURING 30.6 INCHES IN DIAMETER, IN THE
TIONESTA SCENIC AREA.



A SUGAR-MAPLE TREE
MEASURING 29.4 INCHES IN DIAMETER, WITH
BEECH AND HEMLOCK IN THE BACKGROUND.

the smaller forms are the red squirrel, chipmunk, two species of deer mice, the short-tailed shrew and the gray squirrel with a preponderance of black forms. Less common are the red-backed mouse, woodland jumping mouse and smoky shrew. The gray fox and the opossum are southern species also found in the Tionesta. There is a great variety of bird life. Reptiles are not common, but certain amphibians are fairly abundant, and at least nine species of fishes are found in the main streams. Among the vertebrate animals the dominant species are generally Canadian Zone types. This forest is especially valuable for studying the inter-relationships among

all forms of animal life in a relatively unspoiled or natural environment permitting the unhampered working of biologic laws.

The virgin forest has a great influence on the local climate beneath its canopy and generally ameliorates extremes of temperature, reduces wind movement and lessens evaporation. More information on the so-called microclimate of forests and open areas can be obtained. Likewise the influence of the forest on the protection of watersheds through prevention of erosion, streamflow regulation and soil upbuilding should receive detailed study.

HARDY L. SHIRLEY

FOOTPRINTS 100,000,000 YEARS OLD

FURTHER evidence of the prehistoric monsters that roamed the earth millions of years ago, a group of dinosaur footprints perfectly preserved in limestone, has been uncovered in Bandera County,

Texas, by a WPA paleontological project sponsored by the University of Texas.

Considerable scientific interest has been aroused by the find, as these tracks are the first ones that so far have been

discovered in a condition suitable for scientific study. Also interesting is the fact that both the five-toed prints of the huge sauropod or herbivorous dinosaur and the three-toed tracks of the smaller but ferocious carnivorous type were found in the same location.

The tracks were found deeply imbedded in a cretaceous limestone layer underlying some twelve feet of soil along the bank of the West Verde Creek, a few miles southwest of Bandera, Texas. WPA workers, under the supervision of Roland T. Bird of the American Museum of Natural History, carefully cut back the top layers of the soil and gravel and laid bare the prints. The tracks are now being studied and preserved and specimens will be displayed at the American Museum of Natural History in New York City and at the University of Texas Memorial Museum at Austin.

To the trained eye of the scientist the giant five-toed tracks, along the West Verde Creek, tell a story of a whole herd of sauropod dinosaurs which millions of years ago sloughed through the soft, warm mud of an inland sea covering much of Texas. The tracks give evidence of possibly eight or nine of these huge 50-foot-long quadrupeds which belong to the same group as the well-known Brontosaurus. The imprints of one baby belonging to this group were also found.

A perfect row of three-toed, carnivorous dinosaur tracks, cut some three inches deep in the limestone layer, were found. These prints, looking like huge three-toed bird tracks, proceed for fifteen

five-foot strides along the exposed portion. Among the carnivore tracks there are also those of a baby, probably no larger than a kangaroo, according to estimates. These prints give every evidence of being those of the erect predatory dinosaurs which roamed in packs and preyed upon the slower herbivorous sauropods.

It is the curiously rounded, five-toed prints of the mammoth sauropod which has caused the most scientific interest, however. Measurements made at the West Verde site indicate that the largest footprint was 32 inches from heel to toe and that this mammoth amphibian walked with a nine-foot stride. From these measurements it is estimated that the largest of this group was approximately 14 feet high at the hips, was about 50 feet long and weighed more than 10 tons.

Although many fossil remains of the giant sauropod, of which Brontosaurus, the "thunder-lizard," is perhaps the best representative, have been discovered in the western and southwestern portion of the United States and Canada, no clear-cut footprints, adaptable to scientific study, have been uncovered before. This is probably due to the fact that the amphibious sauropod spent most of this time in the water, feeding upon marine vegetation; and the mud flats over which he occasionally wandered were subject to wave action and other elements which would destroy the tracks.

A. S.

THE SCIENTIFIC MONTHLY

OCTOBER, 1941

VITAMIN RESTORATION OF FOODS AS VIEWED BY THE PHYSICIAN

By Dr. RUSSELL M. WILDER

PROFESSOR OF MEDICINE, MAYO FOUNDATION, ROCHESTER, MINNESOTA, AND CHAIRMAN OF THE COMMITTEE ON FOOD AND NUTRITION, NATIONAL RESEARCH COUNCIL, WASHINGTON, D. C.

THE idea of supplementing foods with dietary essentials had its beginning in 1855 when Kostl suggested in Europe the use of natural sea salt or of salt to which had been added potassium iodide. The first use of iodized salt in the United States was begun at the instigation of a Committee of the Medical Association of the State of Michigan. Later iodized salt was accorded "acceptance" by the Council—then the Committee—of Foods and Nutrition of the American Medical Association, and since taking that action that Council has considered favorably addition of vitamin D to milk and canned milk, addition of vitamin A to margarine and of vitamins of the B complex, as well as certain minerals, such as iron and calcium, to wheat flour.

In May, 1939, after much study and discussion, the Council on Foods and Nutrition passed resolutions encouraging, with qualifications, the adding of minerals and vitamins to certain foods in order to restore to them amounts of these substances contained in natural foods. The first qualification was that the addition of only such vitamins and minerals as are in the interest of public health shall be approved, and that the additions shall be made only to the principal human foods in which they naturally occur. Even in these cases the foods to which the additions shall not contain

more of the vitamins and minerals than they do in their natural states, with the following exceptions: (a) vitamin D may be added to milk up to, but not to exceed, 400 units per quart. (b) vitamin A may be added to substitutes for butter up to, but not to exceed, the amount in butter with high natural content of this vitamin. In both cases if the vitamin added is obtained from a natural source there is no objection to its carrying with it one or more other vitamins. (c) Iodine may be added to table salt not to exceed one part of sodium iodide or potassium iodide to 5,000 parts of salt.

In endorsing the principle of restorative "fortification" of processed foods, the council emphasized that every effort should first be directed to retaining in the products the food values of the natural foods from which they were made. If any fortifications are to be permitted, they should be restricted to foods which are suitable vehicles for the minerals and vitamins to be restored. The added substances should mix well and not lose their potency during the usual conditions of storage, and they should be in such form that they will be assimilated by the consumer.

In the interest of public health, improvement of the inexpensive staple foods is primary in importance, and

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In the interest of public health, improvement of the inexpensive staple foods is primary in importance, and

what is done should be effected at a minimal added cost to the consumer. Otherwise added vitamins or minerals will not reach those who are most in need of them.

The aim in restorative fortification of foods is not to reach some hypothetical goal which has no bearing on the problem of human nutrition. It is to provide dietary essentials which people must get from their foods in order to maintain good health. The restored foods should make it easier for the person unskilled or unversed in nutrition to obtain the vitamins and minerals he ought to get with his food.

The policy enunciated in the resolutions of the council referred in particular to the widely used staples. However, the council has accepted some specialty products, including a number of breakfast foods, to which vitamins or minerals or both have been added where the additions do not exceed those in natural foods of the same class. In addition, it has been the policy of the council to consider and accept foods intended for special dietary purposes in which vitamins or minerals are contained or have been added in amounts exceeding those in common natural foods. In such instances acceptance involves compliance with special requirements as to labeling and advertising not demanded for general purpose foods. The thought underlying acceptance of special purpose foods is that they will be used, in the main, on advice received from physicians. Examples of products of this kind are wheat germ, yeast, grass concentrates and fruit juices or cereal products which have more than "restorative" additions of vitamins. Other examples are special foods which are low in carbohydrates or calories.

The Committee on Food and Nutrition of the National Research Council, which now is advisory to the Coordinator of Health, Welfare and Related Defense Activities, was organized in November,

1940, to provide scientific guidance for the national nutrition program which then was being planned. This committee is made up of physicians, nutritional physiologists and others having special knowledge of nutrition. One of the first matters brought to its attention was the scientific testimony that had been given a short time before at the public hearings on flour conducted by the Food and Drug Administration. The committee endorsed the recommendations made at these hearings by several of its members, and then proceeded to give similar consideration to possibilities for improving the nutritive qualities of bread.

With the approval of the Food and Drug Administration the committee proposed to the millers and bakers that they proceed with the manufacture and distribution of flours and breads which would meet the standards recommended for content of thiamine, nicotinic acid and iron. The suggestion was followed, and since then such products have been on the market under the names "enriched flour" and "enriched bread."

Standards for "enriched flour," as proposed by the Food and Drug Administration, were published in the "Federal Register" for April 1, 1941. As there set forth, they closely followed the recommendations of the Committee on Food and Nutrition of the National Research Council. Riboflavin, however, which by the committee had been made an optional ingredient of flour, with the recommendation, however, that it be considered a requirement as soon as adequate supplies of it became available, was included in the federal proposal among the required ingredients.

In the course of the next twenty-one days, a period which the law provides for filing exceptions to proposals for regulations under the Wheeler-Lea Act, objections filed by the industry included objections to the requirement for ribo-

flavin. The matter then was reviewed by the Food and Drug Administration, and a decision was announced by the administrator in the address of Mr. McNutt at the National Nutrition Conference for Defense on May 26, 1941. He stated that the date for the enforcement of the standards had been pushed ahead to January, 1942, instead of having them effective at the end of ninety days, as is usual. This, it was anticipated, would enable manufacturers of riboflavin to provide the required amounts of this vitamin. However, the industries which had cooperated so completely with the program initiated by the Committee on Food and Nutrition were assured that "nothing would be done which would penalize them for events beyond their control." The matter will be reviewed in the fall if necessary.

FURTHER ACTIONS AND OPINIONS

In the meantime, the Committee on Food and Nutrition of the National Research Council, after additional thought and time had been devoted to the general policy involved in modifying foods by additions of vitamins and minerals, had taken two actions. One of these was an expression of policy as follows¹:

The broad policy of the Committee on Food and Nutrition of the National Research Council is to assist in securing adequate nutrition for the greatest number of people. In what it has done to date, consideration has been given and in the future such consideration will continue to be given both to the nutritional requirements and to the supply of essential nutrients in all foods. Every effort has been and will be made to supply this demand through natural foods, and the Committee is emphasizing educational and research projects and other forms of assistance designed to develop methods for the fuller and better utilization of natural foods. However, due to emergency conditions which now exist, specific enrichment procedures may need to be recommended. One has already been recommended, namely, enrichment of flour and bread. Others will be considered individually, each on its own merits.

¹ Council on Pharmacy and Chemistry; Council on Foods, *Jour. Am. Med. Assn.*, 113: 680-681, 1939.

The other action taken by the Committee on Food and Nutrition was in the nature of a recommendation to limit the use of the word "enriched." The recommendation is to the effect that the use of the word "enriched" be restricted to wheat flour and breads made with wheat flour, and that it be not applied to breads commonly known by other designations, such as rye bread or peanut flour bread; also that it be not applied to other foods for which appropriate nutritional improvements may later be recommended.

This action was in no sense discriminatory in favor of wheat bread, enriched in accordance with the recommendations of the committee, over rye bread, soybean bread, peanut flour bread or other products consisting of mixtures of wheat flour with other flour. Also it should be emphasized that "enriched" bread, that is, wheat bread may be enriched not only by additions of purified vitamins or high vitamin yeasts, according to the original recommendations of the committee, but also by processes of milling, whereby the required nutrients, thiamine, nicotinic acid and iron, are retained. To make this point clear the committee now has recommended that breads, such as rye bread, soy bread and other cereal products which meet the standards for thiamine, nicotinic acid and iron, be permitted to indicate that fact on the labeling and in advertising. The suggestion was made, for instance, that in the case of rye bread the label be "rye bread," and under the name the statement, providing the claim can be made truthfully: "this bread meets the standards for enriched bread." At the discrimination of the baker the statement might even be applied to the advertising and labeling of whole wheat bread. Those "in the know" about whole wheat bread would consider such a designation superfluous.

An additional recommendation of the committee was that bakery products other than bread, as bread is defined in Paragraph 2 of Section 3 on page 7 of

the publication named "Service and Regulatory Announcements, Food and Drug Administration." Revision 5, November, 1936, should not be named "enriched," on the ground that cakes, pies, doughnuts and similar products either contain insignificant and highly variable amounts of flour, or if made with "enriched" flour would be subjected to influences in baking destructive to the thiamine contained in the "enriched" flour. However, the committee recommended that no objection be taken to a baker who wishes to display a general statement indicating that the wheat flour used in the manufacture of his products is "enriched" flour.

The decision of the committee to advise that the word "enriched" be not applied to other foods for which appropriate nutritional improvements may later be recommended was based on the opinion that a more appropriate designation than "enriched" could be found for such products.

It is not possible to state at present whether these later recommendations of the committee will be acceptable to the administrative branches of the government. However, administrative regulation must of necessity wait on public hearings still to be held on bread, rye bread and other breads and on rye flour and other flours than wheat flour. In the meantime, the recommendations of the committee are intended to serve as a guide to procedure.

Additional expression of professional opinion in the matter of fortification of foods is to be found in the proceedings of those sections of the recent National Nutrition Conference for Defense in which the medical aspects of the nutritional problem received attention. Chief of them was Section III, on Public Health and Medical Aspects of Nutrition. It met under the co-chairmanship of Dr. James S. McLester and Dr. Richard Smith.

The principal report of Section III contains an endorsement of the action of the Committee on Food and Nutrition of the National Research Council sponsoring enrichment of flour and bread. The subsection, headed by Dr. Smith, was concerned with the nutrition of pregnant and lactating women and of children. In the special report from this section, Section IIIb, fortification was accepted with some reservation. The statement on the subject reads:

It is the opinion of this section that all the scientific nutrients can and should be provided through natural foods. Great progress is being made in the proper milling of grains so as to retain their full nutritive value. Pending further developments in this field fortification of flour may be acceptable.

On the basis of these reports and of reports from other sections of the conference, the recommendations to the President, as formulated by Director M. L. Wilson and unanimously adopted at the last general session of the conference, contain an endorsement of the principle of improving the nutritional value of staple food products by addition to them of nutritive elements that have been removed by processes of milling and refining. It was emphasized, however, that the method should be used with discretion and only on the basis of findings by medical and nutritional experts.

Personal opinions. With minor exceptions my own views on the subject of fortification are in harmony with the pronouncements of these various bodies of physicians and scientists. I am strongly of the opinion that a diet of natural foods represents the ideal way to obtain the nutrients required for health. Where I differ at all from some of the nutritionists is in the emphasis to be placed on those vitamins of the vitamin B complex which now are known to be necessary for the satisfactory oxidation of carbohydrate. They include thiamine, riboflavin and nicotinic acid.

It formerly has been taught that the principal shortcomings of American diets are in the contents of vitamin A and calcium. These can be corrected by supplying more green vegetables and milk, and until recently the major emphasis in the teaching of nutritionists has been on obtaining enough green vegetables and enough milk.

Without in any way minimizing the importance of such teaching, it seems to me that equal emphasis must be placed on providing greater allowances of thiamine, and possibly also of nicotinic acid, than either green vegetables or milk will supply. Milk is a good source of riboflavin but not of thiamine, and neither the leafy nor the tuberous vegetable contains much thiamine. Dr. Jolliffe,² writing in 1938, was the first to focus American attention on this phase of the nutrition problem. The diet of the American of sixty years ago, when the consumption of flour was almost twice that of to-day and the flour was not refined, contained nearly 1,000 international units of vitamin B₁ (3 milligram of thiamine) per day. "The twentieth century American consumes more fresh fruits, vegetables and dairy products. This gives him in many respects a better balanced diet than the American had before 1880, but the accrual from these foods does not compensate for the deficit . . . of vitamin B₁, resulting from loss (of this vitamin) in the milling of our grain and from the lack (of this vitamin) in our sugar." To obtain the lost 550 international units of vitamin B₁ from vegetables and milk a man would have to consume approximately 1.4 pounds of fruit, as much potatoes, 2 pounds of other vegetables and nearly a quart and a half of milk a day, an obvious impossibility.

In point of fact, the present-day diet of persons with liberal incomes rarely contains more than 330 international

units of vitamin B₁ (1 milligram of thiamine), and in families where meat can not be used in reasonably large amounts, the amount of thiamine provided by the diet, as careful surveys have revealed, is less than 330 international units.

INDUSTRY AND NUTRITION

I made a statement to the press some time ago which, widely quoted, has aroused much skepticism and some rather ill-tempered criticism. I want to repeat that statement here in order further to discuss my reason for making it.

I suggested in essence that the low content of thiamine in the diets of urban workers and some of their employers might contribute importantly to the problem of industrial unrest. The suggestion is supported by very good evidence, obtained in the rigidly controlled experiments conducted by my associates, Ray D. Williams and Harold L. Mason, of the Mayo Clinic.³ I mention this additional work of Williams and Mason because of its direct bearing on the point at issue.

In the studies of Williams and Mason, reported this year to the American Institute of Nutrition, eleven volunteer female subjects were placed, for from four to six months, on a diet adequate in every way except in thiamine. The amount of thiamine contained in the diet represented approximately 22 micrograms for each 100 calories. This is very little less than the thiamine reported for the poor diets of several nutritional surveys that have been reported. The subjects later were given additional thiamine without their knowledge. Several of these women had been under observation for a year or more. They and the others were selected because of special willingness to cooperate, previously satisfactory diets and absence

² Norman Jolliffe, *Internat. Clin.*, 4: 46-66, 1938.

³ R. D. Williams and H. L. Mason, *Proc. of Staff Meets. of the Mayo Clinic*, 16: 433-438, July 9, 1941.

of manifest physical or emotional abnormality. After a few weeks on the low thiamine diet all of them became depressed, irritable and quarrelsome. Their meals were attractive in appearance and taste, much more so than the meals routinely provided in the hospital. Their living quarters were pleasant and various diversions were arranged to keep them occupied. In spite of all this it took the greatest tact and diplomacy on the part of the experienced supervising personnel to hold them to the program they previously had agreed to follow. In a few months a "strike" threatened daily, and at the end of six months open rebellion could not be prevented.

Then the thiamine was given, and although the diets were otherwise unchanged and the surroundings remained exactly as they were, the difficulties disappeared and it was possible to continue uninterrupted observations as long as was necessary to obtain the information which the study was designed to provide. This was for periods of from five to seven months. The thiamine was given in very small doses which were increased gradually until the total intake of this vitamin was 2 milligrams a day. After the allowance had reached 1 milligram or more a day all the previous difficulties disappeared. The women then were as willing to work as they had been before the beginning of the study. During the period of restricted intake of thiamine they became disinterested to the point of neglecting their own cleanliness and refusing to make their beds and clean the rooms they occupied. After they obtained thiamine they were quite content to resume the many tasks, such as ward housekeeping, laundry and sewing, that were assigned to them.

An anecdote related by Mr. McNutt at the National Nutrition Conference is one of many that could be cited to illustrate

the effect of malnutrition on the psychologic aspects of industrial situations.

The Tennessee Valley authority went back forty miles behind Norris Dam to the little town of Wilder, a ghost town, a submerged coal town. There several hundred stranded miners' families were barely subsisting, and only the guards at the closed mines ate regularly. Bad actors, vicious, unreliable people, trouble makers, that's what they were; so officials were told. But the officials fortunately were too pigheaded to believe it. They sent a labor representative to Wilder, signed up forty men, put them on regular pay, regular food and hard jobs, and soon these men became some of the best men TVA had.

The importance to industry of the growing knowledge of nutrition is further emphasized by information received from leaders in the field of industrial medicine. In factories to-day, where the most elaborate precautions have been taken to prevent industrial accidents, human errors lead to accidents. They are made by men with training and experience. They almost always seem to be due to inattentiveness and the inattentiveness in turn is attributed to worry. The worried worker, I am told, represents the biggest problem of industrial medicine. Here again inadequate diet, and in particular thiamine deficiency, seem to be contributing importantly. The food of urban workers is notably deficient in many respects. By standards for thiamine based on the Mayo Clinic experiments and now accepted by the Committee on Food and Nutrition of the National Research Council, they are especially deficient in thiamine, and I desire to emphasize the fact that among the first symptoms to develop from lack of sufficient thiamine in the controlled experiments of Williams and Mason were worry, fear, anxiety and inattentiveness.

I do not wish to be understood to mean that thiamine is the only vitamin, lack of which leads to such symptoms as worry, inattentiveness and irritability. It is possible that lack of other vitamins

has similar effects. Nor would I have it supposed that worry, inattentiveness and irritability may not result from many other causes. The main point of my argument is that diets which are inadequate in thiamine have been shown to cause these symptoms.

A section of the National Nutrition Conference for Defense, under the chairmanship of Dr. Frank Boudreau, devoted attention to the nutrition for workers in defense industries. A recommendation from that section reads as follows: "that adequately controlled studies be conducted in selected defense plants to determine the facts concerning the influence of diet on health, working capacity, incidence of accidents, absenteeism and the psychological state, industrial unrest." Workers and employers who cooperate with government or private scientific agencies in carrying on such studies will be performing a major service. Properly controlled investigation can provide the only convincing evidence of the benefits of suitably supplemented diets, and such investigation must be had. In the meantime, in view of the emergency and in the light of experience already accumulated, supplemental feeding in factories is recommended wherever it is found that the diets of defense workers are not fully adequate from the point of view of modern knowledge of nutrition. In England and in individual plants in America where supplemental feeding has been used, efficiency has been increased, accidents have been reduced and the volume of absenteeism has been diminished.

When the question is asked as to what kind of supplemental feeding should be resorted to for factory workers and other groups of persons, we find ourselves in the more contentious field of actual practice. Here I can offer nothing more than bare suggestions. It would seem desirable to avoid the use of purified vitamins as such. Although I have personally

seen great benefit from prescribing 1 or 2 milligrams a day of crystalline thiamine to individual patients whose principal deficiency of diet was, I thought, a lack of sufficient thiamine, in most cases even a mixture of all the purified vitamins probably will not suffice for optimal results. Furthermore, such preparations are much too dear for continuous administration. There is fairly good agreement among those considering this problem that vitamin concentrates are preferable, in general, to isolated vitamins. Natural sources of so-called concentrates are yeast, rice polishings, wheat germ, liver and fish liver oils.

The problem of the industrial plant is not unlike one faced daily in hospital practice, and could be solved as physicians have solved it by providing a mixture of fruit or tomato juice, or a bouillon to which are added suitable extracts of yeast or rice polishings and a drop or two of an oil rich in vitamin A. Whatever is used must be appetizing. Also desirable as a supplement to most diets, because of its calcium and excellent protein, is milk, although milk alone, for reasons I have already given, is not enough.

Except for special purposes I question the expediency of resorting to highly fortified processed foods, although such foods should be tried. A number of them have been developed; one has been accepted by the Council on Foods and Nutrition of the American Medical Association. In England the main resort has been to cooked meals containing several of the protective foods. A practical difficulty with such a procedure is costliness and consumption of time.

FUNDAMENTAL POLICY

This brings me back to the question of fundamental policy. In this policy those of us who provided the scientific testimony at the Federal hearings on flour were in disagreement with the legal ad-

visers of the Food and Drug Administration. In our opinion fortification of general purpose foods was undesirable, and we wanted to recommend that additions of vitamins to flour should be related to the vitamins originally present in the wheat from which the flour came. We recognized that wheats differ in content of vitamins, but anticipated no objection to establishing by definition an arbitrary standard of reference. What we aimed at was an improvement in the nutritive values of flour so that persons using the improved product could more easily plan diets that were satisfactory. We indicated that additions of vitamins to general purpose foods, in excess of the amounts present in natural foods of the class, might not be in the interest of the public health, and expressed a desire to place emphasis on this point of view by designating the suggested procedure, "restoration."

The lawyers, however, were of the mind that because wheats varied widely in their content of thiamine and other vitamins, an arbitrary definition for a standard wheat would not hold up in court, that the additions of thiamine and other nutrients to flour were made in fact to increase the consumption of these nutrients by the consumers of the flour; therefore, that the term, "restoration," was inappropriate and some other designation would be necessary. In consequence we got the word "enriched" and no recognition of our basic philosophy.

The decision of the lawyers may prove best from legal angles. From the scientific point of view it confuses and has led

to misinterpretation. Our single purpose has been to correct a nutritional environment which by the refining of staple foods has been distorted. We are not prepared to improve on nature. The present nutritional knowledge does not justify the attempt. As physicians with patients whom we have examined and can continue to observe, or even for groups of persons who can be held under some degree of medical supervision, as in the case of workers in industrial plants, we may with propriety prescribe vitamins in doses exceeding those to be obtained from diets of natural foods. But the unlimited prescription of vitamins for the public at large is going further than most physicians, including those of us who testified at the hearings on flour, are prepared at present to go.

It is worthy of note, however, that while the principle of "restoration" was obscured at the hearing on flour, the amounts of thiamine, riboflavin, nicotinic acid and iron to be required in "enriched" flour are essentially those which would have been required had the basis of the decision been restoration and not enrichment. We can take some satisfaction in this outcome. In further considerations of fortification of general purpose foods it will continue to be wise, in my opinion, to be guided by the principle of restoration, or restorative fortification, whereby only so much of a vitamin or mineral is added to any food as will impart to the food, with respect to the substances restored or added, the nutritive values of natural foods of the same class.

SIR CHARLES LYELL'S NUGGETS OF AMERICAN HISTORY

By EMILY EVELETH SNYDER

LITTLE FALLS, NEW YORK

EVERY one is agreed that Charles Darwin brought about a revolution in thinking as far as the biological sciences are concerned. Although his theory of evolution fell far short of completely explaining changes in species during the past ages, yet it did stimulate and direct the study of biology to an inestimable degree. It is a well-known fact that after pondering over the material he collected during the voyage of the *Beagle*, 1831-1836, a book he happened to read gave him a clue to the meaning of this material. That book was Malthus's "Essay on Population," published in 1798. Incidentally this same book influenced Russell Wallace, who, half-way around the earth, worked out a theory of evolution which had a marked similarity to Darwin's.

Besides the book that came to Darwin's attention after he had done his collecting, there was another book, given him to read on the outward passage, which was of greatest importance. This was Lyell's "Principles of Geology," published in 1830, and it made Darwin's outlook very different than it would otherwise have been. A former teacher presented Darwin with the "Principles" and advised him to read it but not to believe it. He read it, but far from disbelieving it, he found evidence everywhere that confirmed Lyell's general thesis that the present condition of the earth's surface is the result of changes which have occurred during long, long periods of time. Furthermore, Lyell believed that these changes have been brought about by the same conditions and agencies that were acting at the

moment. His opinion was in opposition to the opinions of those who believed literally in the biblical description of the creation of the earth, and of the catastrophists, and neptunists. The former believed that the earth had experienced a series of violent changes such as eruptions and earthquakes, while the latter believed that floods of tremendous magnitude would account for gorges, hills of gravel, erratic boulders and other like phenomena. Lyell was not the first person to break away from these more dramatic beliefs, but his "Principles" caught the popular fancy and became an epoch-making volume in geology. After Lyell's death Darwin wrote that he owed almost everything he had done in science to the study of the "Principles."

Charles Lyell was born in 1797. His early interest in natural history may be partly explained by the facts that his father was a botanist of some reputation, and that a severe case of measles kept the boy out of school for six months, during which time he collected insects. His eyesight was so much impaired that his biographer tells us that his shortsightedness caused him to stoop. Since the elder Lyell was well-to-do, it was possible for his son to receive a good education and later to spend much time traveling on the continent.

Although he was admitted to the bar, the study of geology became almost an obsession with him and he gave up everything else so that he could devote himself entirely to this science, then in an embryonic state. Since geology must be studied in the field, as long as his health

permitted, he traveled wherever there was a rock formation, a fossil bed, a changing coast line or any manifestations that might give him a clue to the distant or immediate history of the earth's surface.

During 1841-42 Lyell and his wife visited the United States to make geological observations. The information about fossils, coal mines, erratic boulders, drift and other phenomena must have filled his fellow geologists with joy when "Travels in America," in two volumes, was published in 1845. However, as he traveled from Canada through most of the United States east of the Mississippi he made comments on many things not of a geological nature. One finds these interesting bits about the America of a hundred years ago like nuggets in the less colorful matrix of geological information.

His comments are particularly interesting because they are those of an educated Englishman in a country which was regarded with a raised eyebrow, at least, on the island that had so recently lost the Revolutionary War.

How were the visiting scientist and his wife treated? How did they travel? What impressions did politics, education, the institution of slavery and the important cities make on them? Lyell remarks on all these, never for a moment forgetting that he is an upper-class Englishman, yet at times showing a genuine sympathy toward the struggles and problems he saw everywhere.

Their methods of traveling were varied. They crossed from Liverpool to Halifax by steamboat in eleven days and Lyell thought it amazing that friends in the remote parts of Great Britain would have letters from him in less than a month after his departure. River steamboats were everywhere. The trip from Springfield to New Haven was made in one. On the Hudson he was surprised by the boat which went sixteen miles an hour with a load of five hundred passen-

gers. A long narrow steamer from Brownsville to Pittsburgh impressed him because it drew only eighteen inches of water and the single paddle wheel at the stern threw spray like a fountain. The furnace of this boat was exposed to view and the engineers worked on the deck.

He declared the train service excellent in most parts of the country. Between Schenectady and Niagara Falls the long stretches of swamp and forest land impressed him as much as did the cities that appeared suddenly along the way. A striking example of the rapid change coming to the United States was seen in Rochester, New York, where Oneida Indians sold baskets trimmed with porcupine quills, moccasins and birch-bark boxes on one side of the train, while a well-dressed waiter sold ices and confectionery on the other side. In the suburbs of Baltimore the engines were uncoupled from the trains and the cars were drawn into the city by horses.

It was in the South, not the North, where sleet and ice interrupted one trip. While going from Norfolk, Virginia, to Waldon, North Carolina, a rain storm turned to sleet and snow and it was necessary for the engineer to back the train for half a mile, get up steam, dash forward as far as he could and then repeat the operation until they came to a small watering station where they found lodging in a cottage.

Lyell made several remarks about the fact that women traveled unaccompanied in this country without being annoyed. He also mentioned the presence of rocking chairs for ladies in special rooms in some of the trains in the South.

Trains and boats were common, but there were parts of the country where the Lyells were forced to use coaches, private carriages and even to go on horseback. Stage-coach traveling was not without perils. A fellow passenger told him that he had been tipped over thirteen times within three years on trips

between Cincinnati and Cleveland. It was a stage-coach trip that led Lyell to remark that the "coolness and confidence with which every one here is ready to try his hand at any craft is truly amazing." The occasion for this observation was a very rough ride between Geneseo and Dansville. The coach was drawn by four horses and the driver seemed to delight in hitting all the rough spots and getting into all the ruts. Lyell complained and was informed that this was the driver's first experience driving not only four horses, but any horse at all.

During 1841 and 1842 there was much political and economic turmoil throughout the states besides the ever-growing feeling about slavery. The Helderberg War was in its third year and Lyell found the country people between Schoharie and Albany very much excited because a sheriff's officer had just been severely wounded when in "the act of distraining for rent." Although this war was very limited in area, it is interesting because about 100,000 people were living in a mild feudal system on lands owned by the Van Rensselaer family. The tenants had deeds to their farms but paid an annual rent instead of anything on the principal. Stephen Van Rensselaer had not given much attention to the collection of rents and after his death in 1839 the tenants refused to pay his successor. Their resistance was successful because they, dressed as Indians, carried on a reign of terror. They had about 1,500 men as against 700 militia. Trouble continued until 1850, when a trial suit was decided in favor of Harmon Livingston, the head of a near-by manor. Although the right of title was granted to Livingston, a compromise was made and the tenants on the Rensselaer and Livingston grants were able to buy the farms at fair prices.

During the second year of Lyell's visit he was warned against a railway trip from Boston to Providence because of a local war. This war was over

suffrage, for in 1842, Rhode Island was still governed under the charter given it in 1663 by Charles II. Only owners of a freehold worth 134 dollars or renting for seven dollars and the eldest sons of these men had the right to vote. The lower house of the legislature consisted of six deputies from Newport, five each from Providence, Portsmouth and Warwick, and two from each of the other towns. By 1840, Providence had nearly fifteen thousand more residents than Newport, yet Newport was entitled to two more representatives than the larger city. This inequality resulted in the formation of suffrage associations. Then the suffrage associations met in convention and drew up a new constitution. This was voted on favorably and Thomas W. Dorr was elected as governor. The trouble came when the new party tried to take over the government of the state. Governor Samuel W. King called the state militia, which twice dispersed the members of the new party. Dorr was arrested, tried for treason and sentenced to life imprisonment. He was released however in 1847, four years after a constitution framed by the "legal" government was ratified.

This struggle for suffrage and many other incidents made Lyell question the future of a country which allowed nearly every male citizen to vote. He could not believe that it would be very successful and he was confident that no class system could be established. This lack of classes and the hale-fellow attitude of much of the populace distressed him. Lyell was enough impressed by the lack of class feeling to mention the fact that a farmer in New York state had referred to Mrs. Lyell as "the woman" while he spoke of his own daughters as "the ladies." Later in Corning, N. Y., when Lyell wanted his coachman, the innkeeper stuck his head in the bar-room and called out "where is the gentleman who brought this man here?" This consciousness of class was probably not a

personal but rather an English characteristic, for Lyell himself was not knighted until six years after his first visit to America. In one of the rare bits of humor in the book Lyell tells of his indignation when he had to wait from early afternoon until midnight for a coach. The landlord tried to conciliate him by addressing him as "Major."

During the late winter of 1842 the newspapers were full of the extravagant reception given to Charles Dickens. Evidently some Americans thought the matter was being decidedly overdone, but Lyell seemed to think that this adulation was a sign of intelligence, for he reminds the reader that Mr. Dickens was "not a military hero, or a celebrated political character but simply a writer of genius." As far as he was concerned Lyell carried letters of introduction to people in the South in which his friends requested that he be given information and not dinners.

Certainly Lyell's treatment of one celebrated political personage was decidedly brief and unemotional. He disposes of the president (Tyler) in one sentence, "after being presented to the President and visiting several friends to whom we had letters, we were warned by a slight sprinkling of snow that it was time to depart and migrate further southward." The death of President William Henry Harrison, which occurred while Lyell was in this country, is not indexed, but nearly two pages are given to his opinion on the age of the Indian relics near Marietta, Ohio. Here was an English geologist writing in character!

As for the capital of the United States, Lyell was very much discouraged about it. He bemoaned the fact that natural history specimens collected in the Antarctic, the South Seas and California were in the new National Museum in Washington. He felt that it would have been so much more worth-while if they

had been at Philadelphia, New York or Boston because they would have been seen there. But Washington had no university, no philosophical societies, no classes in science or literature and no people who appeared to have any leisure. The members of Congress were living in boarding houses and had left their families in the larger cities where the society was more refined.

Boston, with its clubs and societies, and Harvard College in a suburb appealed to him. In Philadelphia the Lyells lost much sleep because of fire alarms. There was an alarm every one of the five nights they stayed there. To be aroused one night by the procession of firefighters might have been interesting, but five nights of excitement were too much, especially since most of the alarms were false. The first runner blew an unearthly sounding trumpet. Behind him a long team of men pulled the fire engine, its large bell clanging incessantly. A mob of men, many with burning torches followed, and behind them another engine. Evidently Lyell complained of this nocturnal racket, because he was told that the youth of Philadelphia required excitement. He wrote one sentence at the end of this description which he probably hoped the Philadelphians would see. It is, "they manage these matters as effectively at Boston without turmoil."

The problems of slavery were in Lyell's mind and he asked himself what he would do if the solution of the problem was suddenly left to him. After much thinking about the matter he could come to no satisfactory conclusion. He was particularly disturbed by the plight of the free educated Negroes in the North.

The interest taken in education, both in schools and by means of libraries and lectures, gave him an opportunity to express his own ideas and to compare the English and the American attitudes.

That the people of Boston should submit to taxes for instruction amounting to about 30,000 pounds sterling gave him much to think about because it nearly equalled the parliamentary grant for the whole of England in 1841. Factory workers interested in evening lectures seemed to puzzle him. Among the titles of lectures he saw advertised were: Temperance; The History of the American Revolution; The Present State and Past History of China; Travels in the Holy Land; and Meteorology. There were also lectures on Phrenology and he made the comment that the Americans put too much credence in that subject.

Taxes were, as usual, a common subject for complaint in 1841-42. He considered that in Pennsylvania the questions of the tax-assessors were inquisitorial, for among other things the taxpayer was asked how many pleasure carriages he kept, how many watches he owned and whether they were gold or silver.

Several states were on the verge of bankruptcy. Money was not under Federal control and travelers found themselves embarrassed because bills given at the point of departure were sometimes of no value at the destination. Personal notes were a new experience to Lyell. He offered one in payment for a carriage he had used to go to Harper's Ferry only to be told that it was no good. In his attempt to explain what a personal note was the driver confessed that once in Baltimore a friend who ran an oyster store told the driver if he would sign twenty-five of these notes and eat their value in oysters he would circulate them. When Lyell asked the driver if his conscience did not bother him, the man replied that the banks had suspended cash payments and that things would be so bad soon that they would have to get better somehow. Lyell comments that the driver and the oyster merchant "had done their best to hasten on so desirable a crisis."

Although he spent little time socially, Lyell commented now and again on people whose names are still well known to-day. With characteristic brevity he mentions going to a ball given by the citizens of Boston in honor of Prince de Joinville, son of Louis Napoleon. It must have been quite a party, because Lyell says it gave him an opportunity to satisfy himself that the beauty of young American ladies had not been exaggerated by foreigners. He heard a sermon by Channing, a great preacher against slavery. He dined with John Jacob Astor, whose name was familiar in England to the readers of Washington Irving's "Astoria." Lyell was delighted that Astor was planning to found a public library in New York City. At his death in 1848 Astor bequeathed \$400,000 to the city. The Astor Library was located in Lafayette Place at the time it was consolidated with other libraries to become the New York Public Library.

At New Haven Lyell met Noah Webster. When asked how many words he had coined for his dictionary Webster said that he had never coined but one word, to *demoralize*. He had used it in a pamphlet many years before.

Many more scraps of information are scattered through the book. Lyell saw his first humming bird in New Haven, Connecticut. He smelled his first skunk near Cumberland, Maryland. By 1842, he stated, the leading bands of emigrants had reached the Platte River.

Notwithstanding all the variety of different subjects he mentions, "Travels in North America" is primarily a book on the geology of the Eastern United States. Niagara Falls, the anthracite coal mines, Dismal Swamp, fossil shells and bones, rock formations of every kind are discussed with the thoroughness one would expect from the great English geologist. One of Lyell's outstanding characteristics was his open-mindedness, his willingness to change previously held con-

cepts to conform to new evidence. All through the book one senses that he was at a critical point in his thinking. He was inclined to credit icebergs with the formation of what are now known as glacial deposits and with the scattering of erratic boulders. He was still favoring the iceberg theory in 1842, although he did not fail to mention the fact that other scientists believed that North America had been covered with glaciers. By the time the eleventh edition of the "Principles" appeared in 1866, he had accepted the glacial theory.

Niagara Falls was one of the principal things he had come to see. On August 27th he got his first glimpse of the Falls, as the sun shone on them three miles away. There was no building in view, only the green woods and the river. At first he felt that the beauty of the scene exceeded his expectations, but the Falls were "less grand" than he had expected. Perhaps this feeling of disappointment was the result of having recently seen a plate in a book written by Father Hennepin, who, so far as Lyell knew, was the first European to have seen the Falls. In this drawing made by the French missionary in 1678, the Falls appear nearly twice as high as they should and there is a conspicuous additional falls to the left, looking up the river. However, as the days went by and Lyell studied the effects of the water on the rock strata he was almost awed by the power of moving water. The fixed and unvarying appearance of the water tumbling over the cliff surprised him and he was much impressed by the fact that a daguerreotype picture had been made in which one might actually see not only the rocks but even the shape of the clouds of spray.

Lyell devoted considerable time to the anthracite mines. The coal appealed to

him because it burned with so little smoke and did not soil the hands, when touched. But his greatest interests were the method of its formation and the identification of the fossil plants of which it was composed.

After spending a year, lacking about a week, in the United States Lyell left Boston for Halifax. He continued his geological studies in Canada for a few weeks and then returned to England.

Lyell returned to the United States in 1845 and again in 1853 when he was a commissioner to the Industrial Exhibition in New York City.

In 1848 Lyell was knighted and at the time he was summoned to receive the honor he took Prince Albert along the river Dee on a geological trip. The Prince was very enthusiastic. Lyell was made a baronet in 1864.

Now that Lyell had established principles which made it possible to regard geology as a definite science the finding of fossils attained great significance. In 1860 Lyell went to Rhenish Prussia to examine for himself the skull of the Neanderthal Man, then causing great excitement among the scientists. Three years later he brought out the first edition of his now famous "Antiquity of Man." This book went through four editions in ten years.

Sir Charles Lyell died in 1876 and was buried in Westminster Abbey. It has been said of this pioneer geologist, "so long as Lyell lived he learned." What greater tribute could be given to a scientist? Yet probably very few people know anything about his visits to the United States in the last century, or have any knowledge of the importance of the man whose name was given to a mountain in California, near the Yosemite.

ELECTRON MICROSCOPES AND THEIR USES

By Dr. JOSEPH A. BECKER and Dr. ARTHUR J. AHEARN

BELL TELEPHONE LABORATORIES

THREE and a half centuries have passed since Zacharias Janssen, a spectacles maker of Middleburg, Holland, put two lenses in a six-foot-long tube and thereby made the first known compound microscope. In the years since then, the microscope, now grown into a powerful and intricate instrument, has played an important role in the discovery of much of man's knowledge of the physical world. There is, however, much that the microscope has been unable to reveal because of its limited range of useful magnification. To-day, a new type of magnifying instrument, the electron microscope, is extending the range of useful magnification far beyond its old limits and promises to supplement the traditional microscope in many fields of scientific research. In this article, we shall describe types of electron microscopes, tell how they function, and outline how they are being used in physics, chemistry, metallurgy and the biological sciences. A number of pictures will be shown to illustrate these uses.

The electron microscope is similar in the general nature of its operation to the light microscope. In both microscopes, the light waves or the electrons, as the case may be, coming from the object are focused upon an image plane to form a magnified image of the object. No microscope, however, can do this focusing with complete accuracy; hence, there is a limit to the greatest useful magnification that any particular type of microscope can give. For light microscopes this limit is determined largely by the wavelength of the light; thus, with a high-powered microscope of the usual design, we can magnify an object until it is possible to distinguish points on it which

are separated by about half a wavelength but any further magnification results in a blurred image. Unfortunately, light waves are so long that the limit of useful magnification for the usual type of light microscope is only about a thousand fold. This limit of useful magnification has been increased by designing microscopes which employ the shorter ultra-violet light waves and by designing ones in which the space between the object and the lens system is filled with liquids of high refractive index. However, until the advent of the electron microscope, the highest useful magnifications available were but a few thousand fold, and there seemed little prospect that this value would ever be substantially increased.

In 1926, H. Busch showed that beams of electrons could be focused by magnetic fields. Subsequently such beams were also focused by means of electric fields. The development of the electron microscope followed naturally from the discovery of these electron-lens properties of electric and magnetic fields. When the wave nature of the electron was first demonstrated by Davisson and Germer in 1927, the very short wavelengths associated with electrons suggested that this type of microscope should yield useful magnifications far greater than those obtained with light microscopes. This has been verified by experiment. Several different types of electron microscopes have been developed; useful magnifications of almost a million fold have been obtained.

While there is a certain similarity between the electron and the light microscopes, they differ in several important respects: the method of focusing, the

manner of observing the image, the way in which the details of the object are distinguished, and the sources of illumination.

The focusing in electron microscopes is brought about either by magnetic fields, electrostatic fields or a combination of these two. These fields change the path which the electrons follow in much the same way as an optical lens changes the path of light rays. Magnetic "lenses" consist of permanent magnets or electromagnets, while electrostatic "lenses" consist of charged plates with apertures or of coaxial cylinders placed end to end. The magnets or plates are so designed that the magnetic or electric fields have a high degree of symmetry about one axis. These fields must also be so disposed that all electrons coming from a point on the object will again come together at or very near a point in the image plane. This focusing is usually done by changing the potential of one of the plates or by changing the current in one of the electromagnets rather than by changing the relative position of the object, lens and image. The relative position of these parts determines the magnification, and to get high magnifications the object-lens distance must be small while the lens-image distance must be large. Certain simple forms of electron microscopes do not employ lenses. In these the image is formed by a radial projection of electrons from the object-cathode to a screen.

In an optical microscope, we usually see the image directly by looking through the microscope eye-piece, but since electrons are not visible, this can not be done in the electron microscope. By placing a fluorescent screen at the image plane, however, the electron image becomes visible, each part of the screen fluorescing in proportion to the number of electrons hitting it, and the electron density pattern is converted into a visible image. The pattern can be recorded either by

photographing the image on the fluorescent screen or by placing a photographic plate directly in the image plane.

When viewed through an optical microscope, the size, the shape and the other details of an object are revealed because different areas transmit or reflect light with different intensities. Similarly, when an object is viewed through an electron microscope, these details can be distinguished because the different regions transmit or emit electrons in varying amounts. An object may appear quite different in the two types of microscopes. Areas which transmit or reflect light with greatly different intensities may transmit or emit electrons with almost equal intensities, and vice versa. Certain bacteria, for example, which can not be seen with an optical microscope unless they have been dyed, can be seen with the electron microscope in their natural state. Frequently, however, as we shall see in several of the illustrations, photographs made with the two kinds of microscopes appear very similar.

Although the two kinds of illumination, i.e., electrons and light, differ radically, there is a similarity in the way they are used in various types of the two microscopes. Corresponding to light microscopes in which the light (1) goes through a thin object, (2) is reflected from an opaque object or (3) comes from a self-luminous object, there are electron microscopes in which the electrons (1) pass through a thin object, (2) are reflected from a thick object or (3) come directly from an electron-emitting object. Most of the usual methods of causing a surface to emit electrons have been used: heating the object yields thermionic electrons; shining light upon it yields photoelectrons; bombarding it with electrons yields secondary electrons; and subjecting it to intense electrical fields yields field electrons. In studying natural and electron-stimulated phenomena, the electron

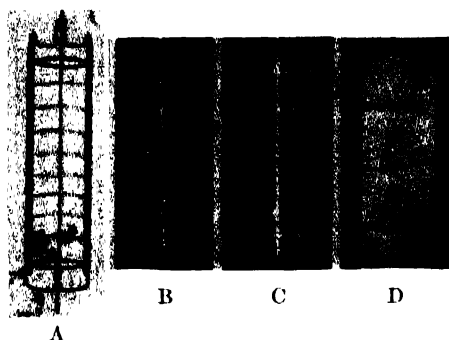


FIG. 1. CYLINDRICAL ELECTRON MICROSCOPE AND PHOTOGRAPHS OF THORIATED TUNGSTEN FILAMENT IN DIFFERENT STAGES OF ACTIVITY TAKEN WITH IT: (A) SKETCH OF MICROSCOPE; (B) FILAMENT AFTER PRELIMINARY TREATMENT; (C) FILAMENT PARTIALLY ACTIVATED; (D) FILAMENT COMPLETELY ACTIVATED (JOHNSON AND SHOCKLEY).

employing one of the above methods of obtaining an emission of electrons from the surface of the object is used. Microscopes in which the electrons are transmitted through the body of the object are used for studying biological specimens and colloidal suspensions. With this as an introduction, let us turn to a description of some of the actual microscopes.

The simplest of the electron microscopes is the cylindrical one developed by Johnson and Shockley, and shown in Fig. 1A. The object, in the form of a fine filament, is placed in the axis of the glass tube, the inner surface of which is coated with a fluorescent screen. The anode consists of a cylindrical spiral of wire in contact with the screen. The tube is evacuated. When the filament is heated and a potential difference of a few thousand volts is applied between the filament and the anode, the thermionic electrons travel radially from the filament toward the screen. There an electron image of the emission pattern of the filament appears. This image is distorted, since along the circumference of the filament the magnification is equal to the ratio of the screen radius to the filament radius but along the length of the filament the magnification is unity.

The pictures shown in Fig. 1B, C and D are of a thoriated tungsten filament in different stages of its activity; they are typical of those obtained with the cylindrical microscope. In B, the wire



FIG. 2. SINGLE CRYSTAL OF TUNGSTEN ON WHICH BARIUM HAS BEEN DEPOSITED—MAGNIFICATION: 250,000 DIAMETERS (BECKER).



FIG. 3. SINGLE CRYSTAL OF NICKEL—MAGNIFICATION: 200,000 DIAMETERS (M. BENJAMIN, GENERAL ELECTRIC CO., LTD., ENGLAND).

has received only preliminary treatment. The small bright lines correspond to small spots where thorium has come to the surface of the tungsten and where, therefore, electrons are emitted more copiously than elsewhere. In C, the filament has been heated at an activating temperature of 1900° K. for a short time. There are more spots and they are longer, indicating that thorium has come to the surface at more places and that it has spread out over a larger area for each active spot. In D, the filament has been fully activated; the bright lines have run together as thorium now covers the entire surface. The horizontal dark lines in these pictures were caused by the anode wires; the more or less vertical streaks in D, by die marks on the surface of the filament. How thorium comes to the surface of this filament is one of the many interesting stories that

the electron microscope has revealed; it will be told more fully a little later.

In a second popular type of simple microscope, one developed by Müller, the cathode consists of a small wire the end of which has been etched to a fine point. This "point," which is actually a hemisphere of very small radius, is mounted at the center of a spherical glass bulb whose inner surface is coated with fluorescent material. When a potential of a few thousand volts is applied to the screen, electron field currents are emitted from the filament. They travel radially to the screen, where an image of this emission appears magnified in the ratio of the screen diameter to the cathode point diameter. Magnifications of half a million or more can be obtained.

If the cathode point is sufficiently small, it will usually consist of only one

crystal. The image on the screen then shows the electron field emission pattern of the various faces of this crystal. Such an image of a single crystal of tungsten on the surface of which there is a small amount of barium is shown in Fig. 2. Here, dark and bright regions form the symmetrical pattern which is characteristic of cubic crystals, such as those formed by tungsten. The small bright spots are places where individual barium ions are adsorbed on the surface. They appear because the electron field emission

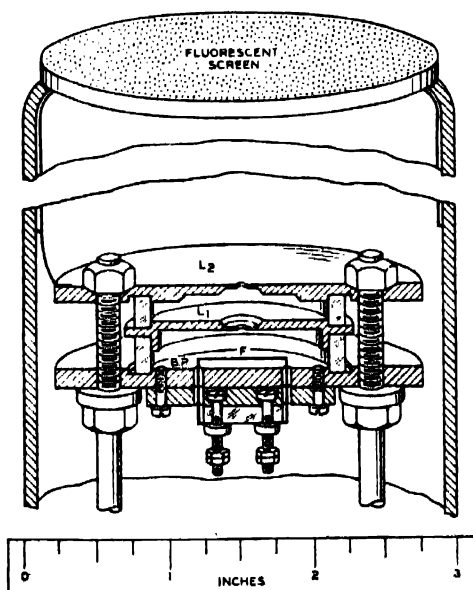


FIG. 4. SKETCH OF MICROSCOPE USING ELECTROSTATIC LENSES (AHEARN AND BECKER).

is enhanced in the neighborhood of each adsorbed ion. A similar photograph of a crystal of nickel shows an interesting and well-ordered pattern (Fig. 3). The magnification for Fig. 2 is 250,000 times; for Fig. 3, about 200,000 times.

Another type of microscope, one developed by Dr. C. J. Davisson and Mr. C. J. Calbick, employing electrostatic lenses, is shown in Fig. 4. The object *F*, is usually a narrow ribbon of metal which, when heated, emits thermionic



FIG. 5. COMPARISON OF ELECTRON AND LIGHT MICROSCOPE PICTURES OF THORIATED TUNGSTEN RIBBON—TOP: ELECTRON MICROSCOPE PICTURE, BOTTOM: LIGHT MICROSCOPE PICTURE (AHEARN AND BECKER).

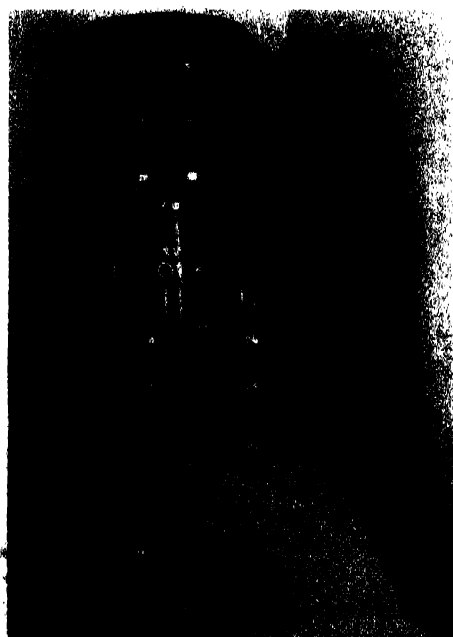


FIG. 6. THE FIRST COMMERCIALY BUILT ELECTRON MICROSCOPE IN AMERICA. IT WAS DEVELOPED AND BUILT BY THE R.C.A. LABORATORIES (AMERICAN CYANAMID CO.).

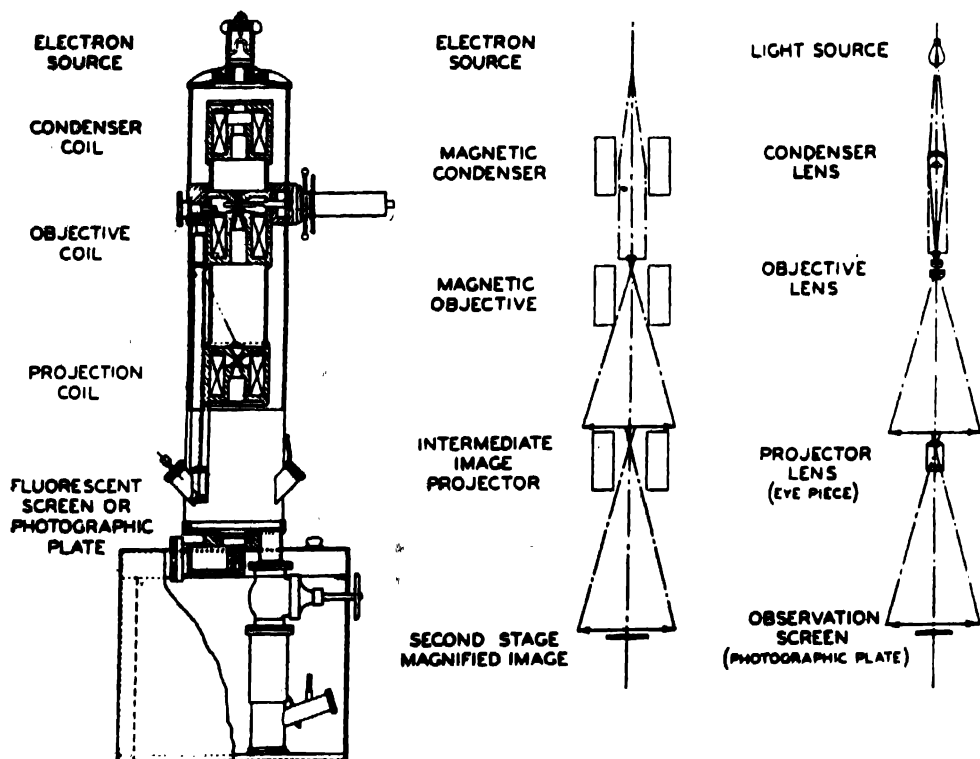


FIG. 7. SCHEMATIC OF "SUPERMICROSCOPE" AND LIGHT MICROSCOPE (R.C.A. LABORATORIES).

electrons. Some of these pass through the small holes in the lenses L_1 and L_2 and are focused onto the fluorescent screen so that they form there a magnified pattern of the object's surface. In a typical case, the potential on L_2 might be two kilovolts and that on L_1 , a tenth as much. With microscopes of this design, magnifications of 50 to 500 are easily obtained.

A picture of a thoriated tungsten ribbon taken with this microscope appears in Fig. 5, together with one taken with a light microscope. A comparison of these pictures shows an excellent agreement in crystal structure as revealed by the two types. Both reveal the grain boundaries as a closely packed series of dark spots, but we notice a much greater difference in electron emission than in light reflection for the various crystals.

The most widely publicized of the

electron microscopes, namely the "super-microscope," uses transmitted electrons and magnetic lenses. This microscope is used to see very thin objects through which a stream of electrons is projected. Microscopes of this kind have been developed by von Borries and Ruska in Germany, by E. F. Burton and his associates at the University of Toronto and by Marton, Zworykin and their associates at the R.C.A. Laboratories. One of these is shown in Fig. 6, and a schematic of it as compared to a light microscope is shown in Fig. 7. A beam of about 50-kilovolt electrons coming from a source at the top of the microscope is made parallel by the condenser lens. The beam then strikes the specimen, which has been placed near the objective lens. Different regions of the specimen absorb or scatter electrons in varying amounts. The electrons pass-

ing through the specimen form a density pattern which the objective lens focuses into an intermediate image. This image is magnified by the projector lens, and the final image is formed near the base of the microscope. Useful magnifications as high as 100,000 times have already been obtained with this microscope and points on the object separated by only a millionth of a cm have been resolved.

Objects to be examined with this microscope are usually mounted on thin sheets of nitro-cellulose. Delicate objects are easily damaged by the intense electron beam. Special techniques have been developed for mounting specimens and inserting them into the highly evacuated chamber. A recently developed form of this microscope has a light microscope built into it, thus permitting simultaneous observation of an object by light and by electrons.

The pictures included in Figs. 8 to 10 show the type of image obtained with the supermicroscope. The first of these compares photographs of *Bacterium coli* taken with the electron microscope and with a light microscope. Both photographs have been enlarged to correspond to an overall magnification of 10,000 times. It is apparent that the amount of detail revealed and the resolving power are much greater with the electron microscope than with the light microscope. Fig. 9 is of a thin filament of a plasticized polymer of vinyl chloride containing 2 per cent. carbon black, magnified 105,000 times. This is a synthetic rubber-like material manufactured by Goodrich. The smallest particles that can be seen here may well be single molecules. In Fig. 10, we can see a particle of face powder, magnified 25,000 times.

Another type of microscope is one employing either photoelectrons or secondary electrons. One use of this microscope is to facilitate the observation of objects by infra-red rays. Infra-red rays that have passed through or have



FIG. 8. BACTERIUM COLI. LEFT: ELECTRON MICROSCOPE. RIGHT: LIGHT MICROSCOPE. MAGNIFICATION: 10,000 DIAMETERS (VON BORRIES AND RUSKA).

been reflected by an object are projected onto a surface which emits electrons when it is illuminated. The emitted electrons are then focused on a fluorescent screen where they form an enlarged picture of the object. When secondary electrons are used, the object is bombarded by primary electrons; if parts of its surface have different secondary electron characteristics, we get a pattern revealing the structure of the surface.

SOME USES OF THE ELECTRON MICROSCOPE

Some of the uses for the electron



FIG. 9. "SYNTHETIC RUBBER"—MAGNIFICATION: 105,000 DIAMETERS (R.C.A. LABORATORIES).

microscope have already been suggested. We shall now turn to a detailed discussion of its use in the fields of physics, chemistry, metallurgy and biology, and particularly in the fields of thermionic emission and adsorption phenomena in which the authors have been chiefly interested.

One of the earliest uses of the electron microscope was the study of thermionic emission, a particular instance being the emission from thoriated tungsten. When a thoriated tungsten filament has been properly treated, the electron emission from it is about 100,000 times greater than that from a pure

tungsten filament at the same temperature. For this reason, thoriated tungsten filaments are used in vacuum tubes. These filaments contain small globules or inclusions of thorium oxide amounting to 1 or 2 per cent. of the volume of the filament. The wires are heated at a high temperature momentarily and then at about 1800° K until a layer of thorium about one atom thick covers the entire surface.

The way in which the thorium arrives on the surface has long been discussed. By using the microscope designed by Dr. Davisson, we have observed how the thorium diffuses to the tungsten surface,



FIG. 10. FACE POWDER—MAGNIFICATION: 25,000 DIAMETERS (R.C.A. LABORATORIES).

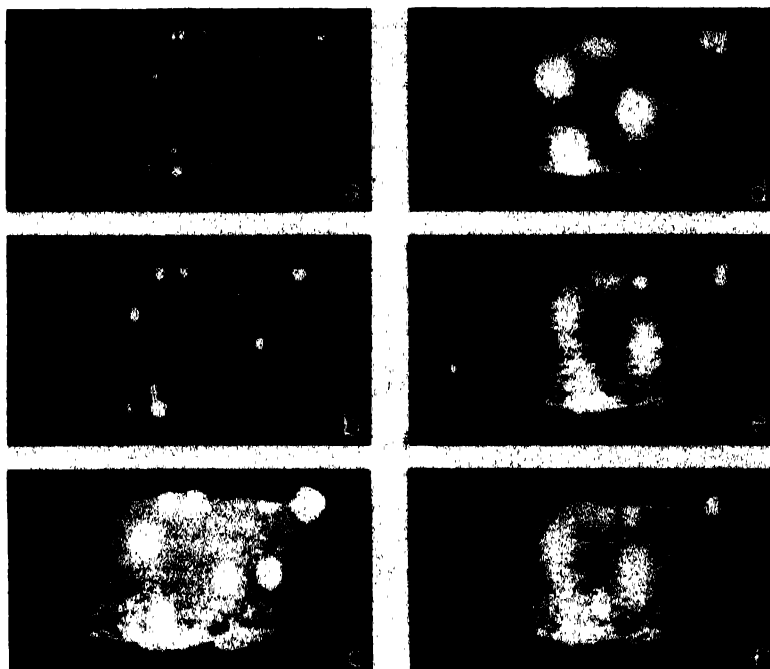


FIG. 11. THORIUM ERUPTIONS ON A SMALL GRAINED THORIATED TUNGSTEN RIBBON (AHEARN AND BECKER).

how it migrates and evaporates and how the crystal structure of the tungsten influences these processes.

Two series of pictures of thoriated tungsten filaments, taken while they were being activated, appear in Figs. 11 and 12. Fig. 11 shows a fine-grained filament. The first picture was taken after the filament had been flashed at 2500°K . Here there are a few bright spots of high electron emission where the thorium has come to the surface. The following pictures were taken after the filament had been heated successively longer times at its activating temperature of $1800\text{--}1900^{\circ}\text{K}$. The spot in the right center region shows a typical history. It grows both in size and intensity for a while and then becomes dimmer as its size further increases. Other spots go through the same sequence, but their sizes at maximum intensity vary considerably. Occasionally

new spots appear and, in turn, go through the same sequence.

Fig. 12 shows the activation of a coarse-grained filament. Here the spots are much larger: in *d*, one of them has covered the entire width of the filament. In *b*, we see two spots on a single crystal which are growing more rapidly in one direction than in others. In *e*, there is a spot which has just started at the junction of several grain boundaries.

From these pictures, we can see that the thorium comes to the surface through a small opening and then spreads out and that only a limited amount of thorium comes through any one opening. Because of the resemblance to volcanic eruptions, these phenomena are known as "thorium eruptions." We are led to the hypothesis that these eruptions are caused by the thorium oxide inclusions in the tungsten and that when an eruption occurs, all the oxide in a single

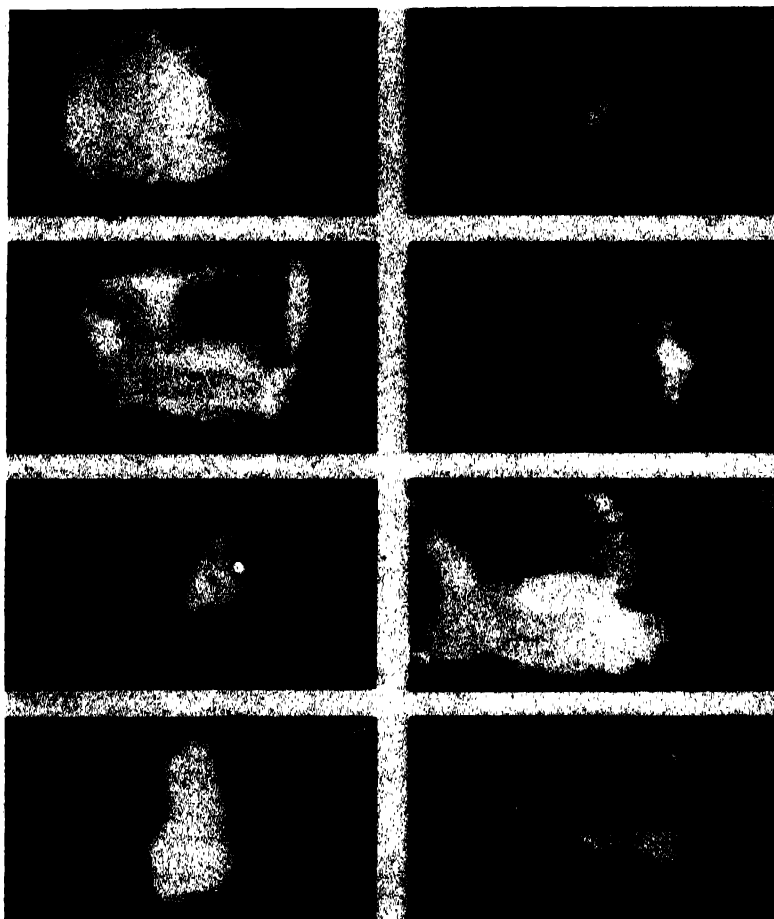


FIG. 12. THORIUM ERUPTIONS ON A LARGE GRAINED THORIATED TUNGSTEN RIBBON (AHEARN AND BECKER).

inclusion is reduced to metallic thorium, which then comes to the surface.

Photomicrographs of sections of these thoriated tungsten filaments show the inclusions. Such a photomicrograph for the fine-grained filament is in Fig. 13. On the large grain filament the inclusions are larger than on the small grain one. They tend to congregate along the grain boundaries. Their total volume amounts to about 2 per cent. of that of the filament, and their distribution in size agrees well with that calculated from the electron images of thorium eruptions. All these facts confirm the

hypothesis that when an eruption occurs, approximately all the thorium in an inclusion of thorium oxide comes to the surface.

When eruptions occur on a polycrystalline filament, the thorium migrates with equal ease in all directions. This was shown in Fig. 11. When these eruptions occur on a single crystal, the thorium tends to migrate in a preferred direction. This is shown in Fig. 14. From x-ray studies of this crystal, the preferred direction was found to be the 111 direction on a 211 plane. In this direction, the neighboring rows of tung-

sten atoms are the most widely separated, and evidently the potential hills which a migrating thorium atom encounters are the smallest.

How the emission from various crystals of tungsten depends on the amount of adsorbed thorium can be seen in Fig. 15. Picture *a* is an electron image of a tungsten surface on which there is only a small amount of thorium; picture *b* is of tungsten with a high concentration of thorium; the following ones represent successively lower thorium concentrations. We see a number of crystals which are relatively bright in *a* and relatively dark in *b*. In pictures *d* and *e*, which correspond to intermediate concentrations of thorium, the contrast between different crystals is slight. This reversal of pattern must mean that if crystal A is less active than B when their surfaces are clean, then A will be the more active of the two when sufficient thorium is adsorbed on their surfaces.

The spherical microscope has been used successfully to study the electron emission of tungsten surfaces on which barium has been deposited. In Fig. 2, we saw a single crystal of tungsten with a small amount of barium on its surface. Because of this barium, the bright regions in the pattern do not appear uniformly bright. Apparently the electron emission comes mainly from small spots, five or six atomic distances in diameter, on the tungsten surface. We believe these spots are caused by individual barium ions. Because these ions are positively charged and are close to the surface, they produce strong fields in their neighborhood. These fields range as high as 10 million volts per cm very close to the ions and probably have high values for distances of several atom-diameters from them; as these fields are in the same directions as the one caused by the applied potential, the electron emission near these ions is much greater than elsewhere. If the number of these

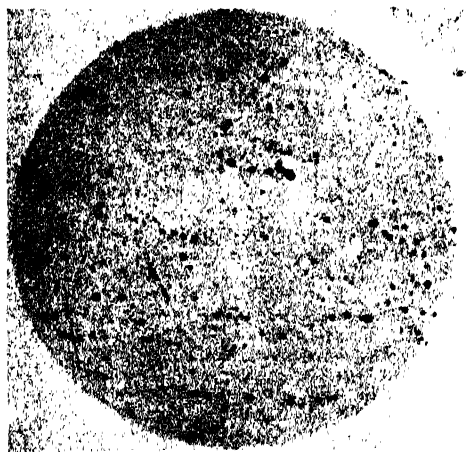


FIG. 13. PHOTOMICROGRAPH OF INTERIOR SECTION OF FINE GRAINED THORIATED TUNGSTEN RIBBON. MAGNIFICATION: 850 DIAMETERS (AHEARN AND BECKER).

spots in a given area is counted, it is possible to compute the decrease in work function for such a surface. This computed decrease agrees with that observed experimentally. Occasionally a spot becomes brighter for ten to thirty seconds or disappears temporarily. In the latter case, we believe the ion has attracted an electron and has become temporarily a neutral atom. When the spot becomes unusually bright, we believe the ion has lost a second valence electron and thus the field near it has become even higher than before. It is



FIG. 14. MIGRATION OF THORIUM OVER THE SURFACE OF A SINGLE CRYSTAL OF THORIATED TUNGSTEN (AHEARN AND BECKER).

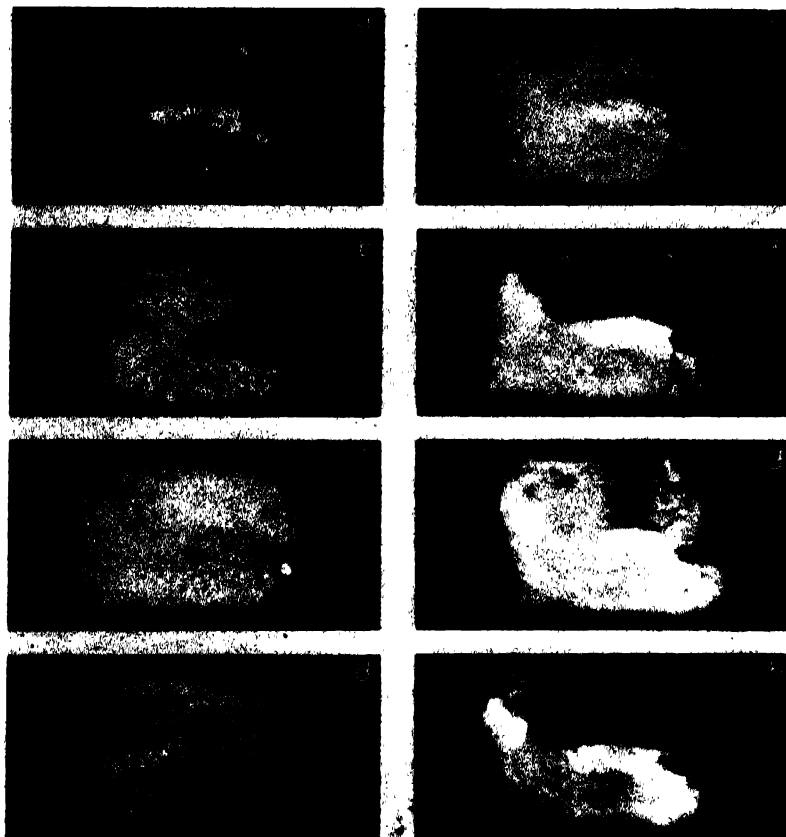


FIG. 15. CHANGE OF ELECTRON EMISSION FROM TUNGSTEN RIBBON WITH CHANGE IN AMOUNT OF ADSORBED THORIUM. A. LOW THORIUM CONCENTRATION; B. HIGH THORIUM CONCENTRATION; C TO H. SUCCESSIVELY LOWER THORIUM CONCENTRATIONS (AHEARN AND BECKER).

only with low barium concentrations that these spots can be observed; as the amount of barium is increased, the spots become more numerous and run together.

If this tungsten point is heated to 840°K , the spots at the edges of the central area begin to move about. When the temperature is further increased, all the spots become agitated, and individual spots merge with their neighbors. This demonstrates that these ions are not rigidly anchored to the tungsten, that they bounce about over the surface. When their average kinetic energy, which increases with temperature, becomes great enough, this "thermal agi-

tation" becomes visible in the microscope. If the barium is deposited only on one side of the tungsten point, it is possible to observe the barium migrate to the other side and cover the whole surface. This migration begins at about 900°K .

As the amount of barium on the point is increased, the anode potential that is needed to get a visible image on the screen decreases. With increased barium, the distribution of the bright and the dark regions changes, but the symmetry stays the same. If thorium is substituted for barium, similar results are obtained. This is beautifully shown in Fig. 16. The pictures, from the work

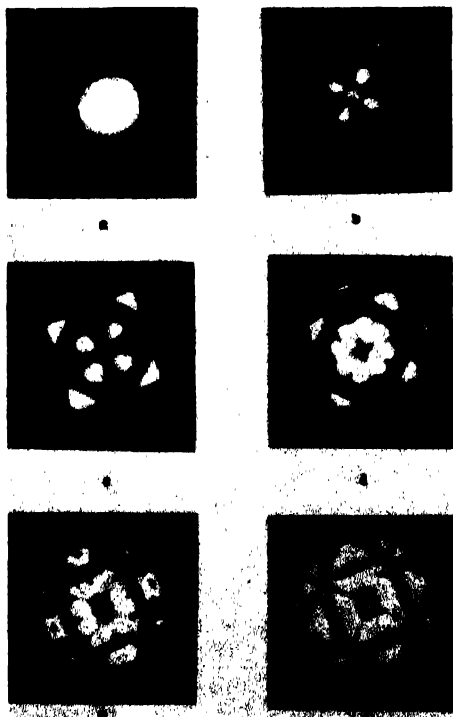


FIG. 16. TUNGSTEN SINGLE CRYSTAL POINT WITH PROGRESSIVELY LARGER AMOUNTS OF ADSORBED THORIUM (AMOUNT OF THORIUM INCREASED FROM A TO F) MAGNIFICATION: 91,000 DIAMETERS (M. BENJAMIN, GENERAL ELECTRIC CO., LTD., ENGLAND).

of Dr. M. Benjamin, represent progressively larger amounts of thorium on a single tungsten crystal. The same symmetry appears whether the surface is clean or is heavily coated with thorium.

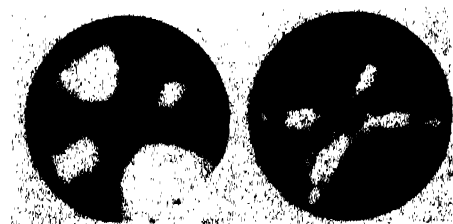


FIG. 17. EFFECT OF ADSORBED OXYGEN ON EMISSION FROM TUNGSTEN: LEFT, CLEAN TUNGSTEN; RIGHT, TUNGSTEN COVERED WITH OXYGEN (MÜLLER, BERLIN).

It is interesting to note that as the thorium concentration changes, some of the dark areas become the brightest ones, and *vice versa*.



FIG. 18. GRAIN GROWTH IN THORIATED TUNGSTEN. A. 2400° K, 60 MINUTES; B. 2600° K, 4 MINUTES; C. 2600° K, 2 MINUTES; D. 2600° K, 1 MINUTE; E. 2630° K, 1 MINUTE; F. 2700° K, 30 SECONDS (AHEARN AND BECKER).

The spherical microscope has also been used to study adsorption of oxygen. With this microscope, the field emission pattern of a clean tungsten crystal can be observed and compared with the pat-

tern of the same crystal after a large amount of oxygen has been adsorbed by its surface. Such a comparison is illustrated in Fig. 17 and reveals a reversal in pattern similar to that noted in the discussion of the effects of large amounts of thorium on the thermionic emission of tungsten. The oxygen, however, hampers rather than facilitates the emission; twice as high a field is required to observe the oxygen contaminated surface as is needed to observe the clean one. When the tungsten is heated at

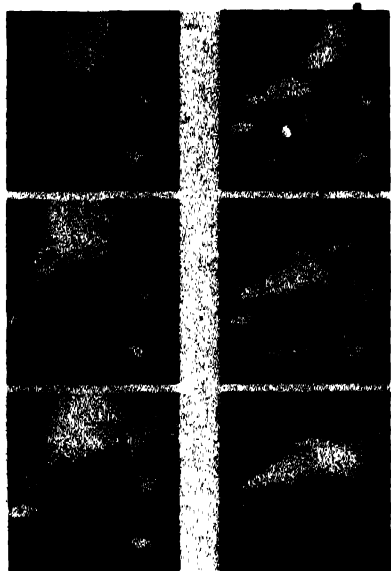


FIG. 19. CRYSTAL TRANSFORMATION IN IRON. TO LEFT OF WHITE LINE: BETA IRON. TO RIGHT OF WHITE LINE: GAMMA IRON (BURGERS AND PLOOS VON AMSTEL).

successively higher temperatures to reduce by steps the amount of oxygen, the pattern changes in a complicated way and finally returns to that corresponding to the clean surface. From such changes in the activity of various parts of a crystal surface, the physicist and the chemist can learn something of the forces in adsorption and of the charges on adsorbed atoms and ions—forces and charges that play a deciding role in

catalysis. It seems probable that the electron microscope will prove of considerable value in the study of these important phenomena.

The now familiar difference in the electron emission from different crystal faces of the same metal has suggested the use of the electron microscope to the metallurgist. In particular, it gives him an easy method of studying grain growth and crystal transformations in metals by permitting continuous observation of these changes as they occur. Fig. 18 shows this grain growth in thoriated tungsten as revealed by such a use of the electron microscope. In *a* the filament had been heat-treated at 2400° K only for about 60 minutes. In the succeeding pictures, short-time heat treatments at 2600° K to 2700° K were given. The large grain growth first appears in the lower right-hand corner and eventually absorbs most of the field of view into a single crystal. In *f*, a little island of the original polycrystalline tungsten still persists. As a result of further heating, this island was completely absorbed into the single crystal.

Another example from the field of metallurgy showing how the electron microscope makes short work of otherwise tedious jobs is the study of crystal transformation in iron. Above 906° C iron atoms arrange themselves in the face-centered cubic lattice; this is known as the Gamma phase. Below 906° C they are arranged in the body-centered cubic lattice; this is called the Beta phase. Fig. 19 shows a series of electron images in which Gamma iron is transformed into Beta iron. To photograph these electron images, the iron was first covered with strontium in order to get a satisfactory electron emission at the transformation temperature. The first picture is that of Gamma iron slightly above 906° C. In the following ones, the temperature has been reduced below 906° C. Since a temperature gradient

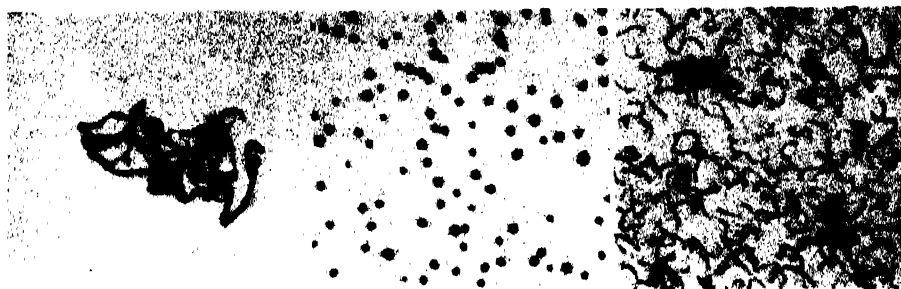


FIG. 20. PHOTOGRAPHIC GRAINS. LEFT: A SILVER BROMIDE CRYSTAL WHICH HAS BEEN DEVELOPED BY THE USUAL CHEMICALS. CENTER: A LIPPMANN EMULSION MADE BY PRECIPITATING COLLOIDAL SILVER BROMIDE. RIGHT: THIS EMULSION AFTER CHEMICAL DEVELOPMENT. EACH CRYSTAL WAS LENGTHENED INTO A THREAD ABOUT 5 ATOMS THICK. MAGNIFICATION 125,000 DIAMETERS (EASTMAN KODAK RESEARCH LABORATORY).

exists along the wire because of end-cooling, the transformation begins at the end (the left in these pictures) and progresses toward the center. A white line has been drawn on the pictures to show the boundary between Beta iron on the left and Gamma iron on the right. By raising the temperature above 906°C , the iron is reconverted into the

Gamma phase. Similar use has been made of this microscope to study the same type of transformation in other metals.

Use of the transmitted-electron type of microscope has revealed a variety of phenomena of interest to colloidal chemists and to bacteriologists. In one study, it was found that the silver grains in a



FIG. 21. FINE PARTICLES OF MAGNESIUM OXIDE. MAGNIFICATION: 56,000 DIAMETERS (AMERICAN CYANAMID CO.).

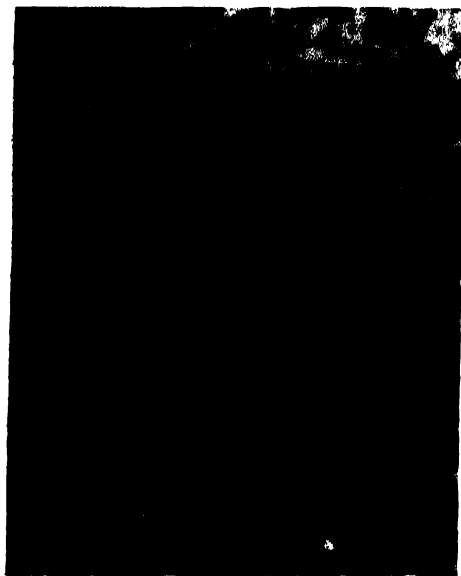


FIG. 22. COLLOIDAL CARBON BLACK PARTICLES. MAGNIFICATION: 48,000 DIAMETERS (A. PREBUS AND COLUMBIAN CARBON CO.).

photographic film resemble loose balls of thread rather than compact particles (Fig. 20). Work on fine powders has revealed that very minute particles have the same crystal structure as the corresponding large particles, thus disproving a widely held theory (Fig. 21). From photographs, such as the one in Fig. 22, the size and shape of colloidal carbon particles have been determined. The size of these particles, which has long been the subject of research, was found to be considerably smaller than that revealed by earlier techniques.

Examination of bacteria by means of this microscope has revealed that many types of bacteria, including streptococci, pneumococci, bacillus subtilis, coliform

and typhoid bacilli, have rigid outer membranes or shells which protect their inner structure. Other bacteria have been found to have long, apparently tubular arms by means of which they probably are able to move around. An investigation of the reduction of tellurides to metallic tellurium by diphtheria bacilli showed that crystals of tellurium form in all parts of the microorganism and that, in some cases, the crystals grow large enough to puncture the walls of the bacillus. The electron microscope has also been used to locate magnesium and calcium in striated muscle tissue. A number of photographs made with this microscope of microorganisms were included in a recent issue of *THE SCIENTIFIC MONTHLY*¹ and show some of the interesting details that the electron microscope has revealed.

We hope that this review of various electron microscopes and their uses has served as an introduction to this interesting new instrument. How greatly the electron microscope will contribute in the future to an increased knowledge of nature and to the advancement of man, one can only guess. But, with the light microscope still proving of immense value after centuries of use, it seems more than likely that the contributions of the electron microscope will prove both numerous and significant as its development progresses and its use becomes wide-spread.

The authors acknowledge with thanks the valuable assistance of Mr. E. P. Churchill, Jr., in preparing this manuscript.

¹ T. A. Smith, *SCIENTIFIC MONTHLY*, 52; 4, 337, April, 1941.

ASPECTS OF URBAN AND INDUSTRIAL GEOGRAPHY IN TASMANIA

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TASMANIA affords opportunities for the study of urban centers and tributary rural districts in relatively mature stages of development under the Australian environment. Most mainland states are less far advanced in the exploitation of natural resources, and their populations continue to expand at fairly rapid rates, especially in the larger cities.

In Tasmania agricultural activities, which have always been the backbone of development, display few signs of expansion or change. Little new land is available and specialized forms of agriculture, for which Tasmania has certain inherent advantages, are more significant than general pastoral or farming activities. Known mineral deposits of better grade and the more accessible timber supplies have been largely exhausted with the inevitable effects on dependent population groups. Manufacturing enterprises of many types have declined in competition with larger establishments on the mainland, although the development of cheap hydroelectric power has recently brought several important new industries to the island. Recreational activities afford an increasingly important source of income to an area steeped in tradition and scenery and situated on the periphery of modern Australian development.

Tasmania's rate of population growth has been least rapid among all the Australian states since the beginning of the twentieth century. In numerous years, especially since 1918, the population has shown substantial losses due largely to emigration but due also to declining birth rate. Although the larger cities

show a slow growth, urban opportunities are insufficient to prevent a considerable migration of young people to the nearby mainland.

Tasmania is least highly urbanized among the Australian states. Only 52 per cent. of her population of nearly a quarter million resides in cities as compared to 69 per cent. in New South Wales. Tasmania also ranks lowest among the states in the proportion of its population concentrated in the capital city. Hobart and its suburbs contain only 27 per cent. of the state's population as compared to 55 per cent. in Melbourne. Fifteen per cent. of Tasmania's population is concentrated in Launceston, thus giving the island a second city of great relative importance.

The lesser degree of centralization of population, commerce and industry in Tasmania has its origin in the historical development of the state as well as in the arrangement of physical forms. Hobart and Launceston, by virtue of their early establishment at strategic positions at the north and south ends of the island, command the trade of the state and dominate most aspects of its political, social and economic life (Fig. 1).

An examination of the circumstances surrounding the original selection of the sites for Tasmania's two principal foci of settlement, coupled with a brief account of their early growth, affords a helpful background for understanding later aspects of the state's urban and industrial development. The high degree of success to which sites originally selected for penal purposes later served as centers for modern urban activities

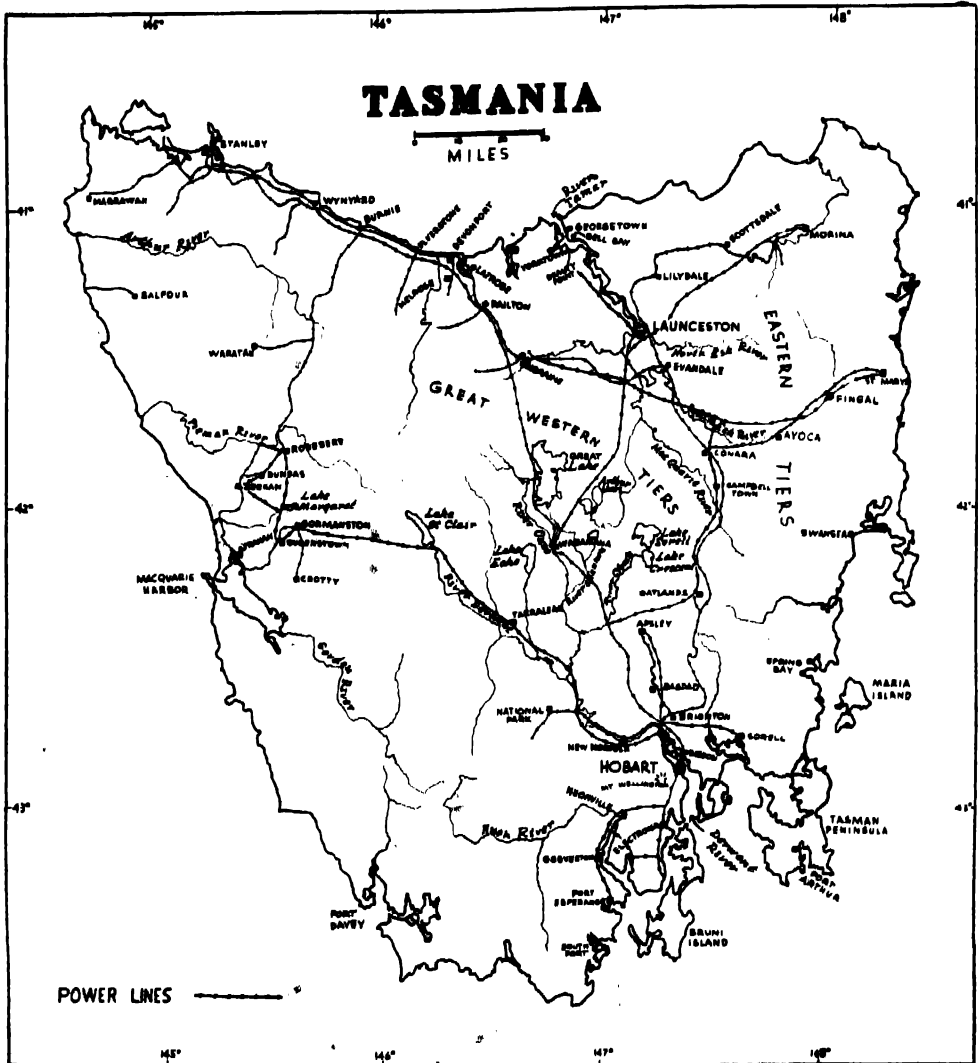


FIG. 1. LOCATION MAP OF TASMANIA
SHOWING THE PRINCIPAL PHYSICAL FEATURES, SETTLEMENTS, RAILWAYS AND POWER LINES.

is one of the most interesting aspects of Tasmania's occupation.

OCCUPATION OF THE HOBART SITE

In the initial occupation of Australia the British were not concerned primarily with colonization in the usual sense but rather with the creation of isolated centers to receive prisoners dispatched from the home country. When Sydney became "over-crowded"

convict stations were established elsewhere along the coast. Tasmania, with its insular form and small extent (26,215 square miles) was especially suitable for penal colonies and it was used for such purposes until 1853, or long after most centers had been abolished on the mainland. The first half century of Tasmanian history was largely concerned with penal establishments and the second half century was much taken up with



FIG. 2. SMALL COVE ACROSS THE DERWENT RIVER
MARKING THE SITE OF THE ORIGINAL SETTLEMENT ATTEMPTED BY BOWEN AT RISDON.



FIG. 3. VIEW FROM BELLEFIVE ACROSS DERWENT ESTUARY TO HOBART
THE SUBURBS OF HOBART SPREAD FOR SEVERAL MILES ALONG THE BASE OF MT. WELLINGTON.

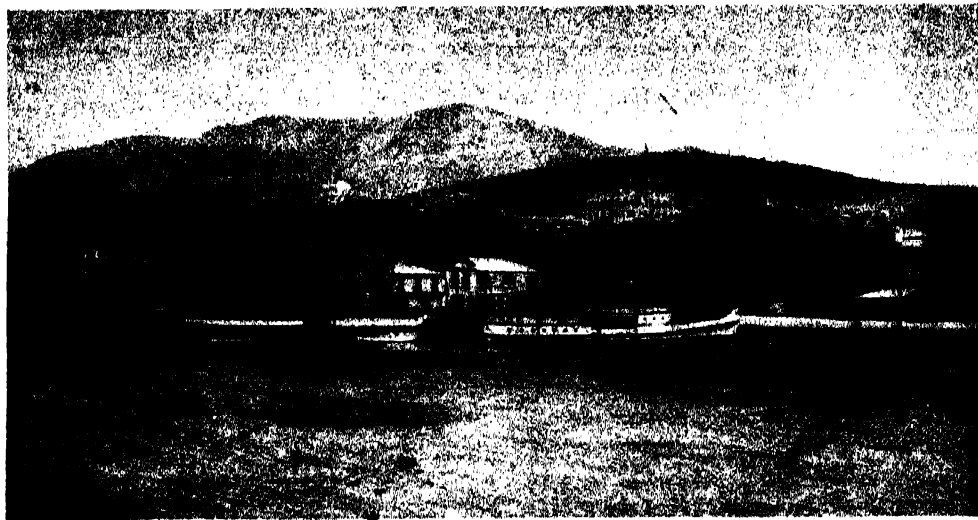


FIG. 4. ACROSS COMMERCIAL DISTRICT OF HOBART TO MT. WELLINGTON
THE FOREGROUND CONSISTS OF RECLAIMED LAND ALONG THE MAIN WATERFRONT.

overcoming the effects of those institutions. Gradually and inevitably, however, emancipists, retired military men and free settlers created the substantial type of occupation which now characterizes both urban and rural portions of the state.

In 1803, John Bowen was commissioned by Governor King at Sydney to establish a small group of convicts and soldiers along the Derwent River in southern Tasmania. A site at Risdon Cove, 16 miles from the entrance of the drowned river course, was specified in the orders, largely on the basis of the favorable account of the location by the explorer Bass (Fig. 2). A town was to be laid out and farm land cleared by the convicts. Risdon Cove appeared at the time to be suitable for a small settlement, but its anchorage was lacking in depth, the fresh-water supply proved inadequate at times, agricultural land was scarce in the narrow valley, and hills interfered with even limited expansion of the settlement. Taking into account the physical limitations of the site and the character of the human materials, the failure of the establishment would now seem to have been inevitable.

In 1804, a detachment of prisoners and soldiers under the leadership of David Collins arrived at Risdon Cove after an unsuccessful attempt to create a settlement at Port Phillip on the north side of Bass Strait. The strategic importance of securing a hold on the strait between Tasmania and the Australian mainland was recognized as soon as Tasmania was proved to be a detached body of land in 1798.

The unsuitability of Risdon Cove for an extensive and permanent settlement was immediately recognized by Collins, who selected a site at Sullivan's Cove on the opposite side of the river and four miles nearer its entrance. The site lay at the foot of Mt. Wellington; extensive tracts of gently sloping land were available; timber and building stone were abundant; a mountain stream provided an ample flow of fresh water; and a deep anchorage was immediately available alongside a small island near the shore. By the end of the year the Risdon Cove settlement was abandoned and Hobart became the administrative center for the south half of the island (Fig. 3).

"The Camp," as it was commonly called, on Sullivan's Cove spread with-

out prescribed form along the margin of the bay and a short distance inland to a rivulet, the banks of which were bordered by a dense growth of brush and trees. Small boats and supplies were held in tents under heavy guard on the small island in the cove where unloading was easy and where they were relatively safe from plunderers. At low tide the island could be reached from the mainland along a connecting bar. A quarry was opened in a ledge of sandstone near the waterfront to provide foundation materials. Shells gathered from the waterfront were burned for lime. "Wattle-and-dab" huts with thatched roofs became the characteristic early house-type. The initial settlement consisted of about 250 individuals, but it was supplemented at irregular intervals by the arrival of convict ships (Fig. 4). In keeping with the maintenance of a prison camp merchant vessels were prohibited from entering the Der-

went River. With the rapid increase in convict population at Hobart during the early years the problem of subsistence was at times a difficult one, according to the account of J. B. Walker in his "Early Tasmania."

In 1810 Hobart contained about 150 houses scattered irregularly over the site. On the occasion of Governor Macquarie's visit in 1811 he appointed surveyors to draw up a town plan on which he named the principal streets. Cancellation by the Colonial Office in 1813 of the order prohibiting vessels from discharging cargo in Australian settlements without first calling at Sydney promoted the development of commerce at Hobart. The adaptability of the Derwent estuary for overseas commerce was conclusively demonstrated at that early time (Fig. 5). Overseas mail for the entire island was normally received at Hobart, and that destined for northern centers was sent overland. An "improved" road



FIG. 5. NEWTOWN AND OTHER NORTHERN SUBURBS OF HOBART SPREAD OVER THE ROLLING FOOTHILL BELT BETWEEN THE MT. WELLINGTON UPLAND AND THE DERWENT ESTUARY. SPLIT PALING FENCES, SIMILAR TO THE ONE IN THE FOREGROUND, ARE CHARACTERISTIC THROUGHOUT TASMANIA.



FIG. 6. GENERAL VIEW TO THE NORTH OVER PRESENT-DAY HOBART SULLIVAN'S COVE CORRESPONDS WITH THE SITUATION OF THE PRINCIPAL WHARVES SHOWN AT THE EXTREME RIGHT. THE SITE OF RISDON IS AT THE FOOT OF A LOW MOUNTAIN MASS SHOWN IN THE CENTER DISTANCE AND ON THE OPPOSITE SIDE OF THE ESTUARY. THE DERWENT ESTUARY PENETRATES DEEPLY INTO THE LOWLAND AND PROVIDES MANY MILES OF ACCESSIBLE WATERFRONT FOR URBAN DEVELOPMENT.

connected Hobart with Launceston via the midland route as early as 1818. By 1821, Hobart possessed a population of 2,700 and 421 substantial houses, all fronting on regular streets, the pattern and names of which are preserved in the modern city (Fig. 6).

OCCUPATION OF THE LAUNCESTON SITE

Late in 1804, or shortly after the establishment of Collins at Hobart, an expedition was dispatched from Sydney under William Paterson* to occupy a suitable site on the Tamar River in northern Tasmania. In fact, when Collins found the entrance to Port Phillip on the mainland side of Bass Strait to be unsuitable for a settlement, he considered seriously the immediate transfer of his group to the Tamar district. Chance rumors, however, as to the difficulty of entering the Tamar and the unfriendly attitude of the aborigines probably were the determining factors in directing Collins to the easily navigable and better known Derwent instead. The prime purposes in the establishment of a post near the mouth of the Tamar were to forestall any attempt on the part

of the French to occupy Bass Strait and to afford protection to English sealers against American interlopers among the channel islands.

The accidental grounding of Paterson's flagship on a shoal on the east bank of the river entrance led to the preliminary occupation of the nearby site of George Town. Sufficient water was available along with suitable timber for the construction of huts to house the expedition of nearly 150 persons. Some cultivation was attempted while a careful survey of the Tamar was in progress.

A site at the head of Western Arm soon attracted Paterson's attention. Two streams of fresh water, ample timber and proximity to the sea were its favorable qualities. Western Arm, however, was not navigable by large vessels, and agricultural lands were neither fertile nor abundant.

At the head of the Tamar estuary extensive tracts of rich pasture land were found with only scattered trees to interfere with cultivation of the fertile soil. The site was regarded as ideal for an agricultural settlement, and although it lay 42 miles inland the Tamar provided a highway to the sea (Fig. 7).

Contrary to one's expectation the site on Western Arm was selected for the new settlement. The choice can be justified only with the knowledge that the government was interested principally in the establishment of a military center near the coast at which a number of convicts could be quartered to advantage and not in the creation of an extensive self-sustaining free settlement.

The site of York Town was marked out for the erection of quarters and haste was made in order that the group, now increased to some 200 by the arrival of additional convicts, could be settled before the arrival of winter. A brief occupation of York Town merely emphasized the advantages possessed by the Launceston site and Paterson recommended that a town site be reserved and farm lands be made available to settlers. In March, 1806, Launceston became the headquarters for agricultural settlement in northern Tasmania. The 42nd degree of latitude served to divide Cornwall County in the north with Launceston as

its administrative center from Bucks County in the south with Hobart as its chief settlement. York Town was essentially abandoned by 1810.

Although Launceston was in most respects admirably suited for settlement purposes, the need for a port near the mouth of the Tamar was repeatedly expressed. Only vessels of less than 12-foot draft could reach Launceston. Governor Macquarie visualized the agricultural future of Launceston but also believed that George Town was destined to become a great commercial port. With the approval of the Colonial Office given in 1814, the governmental headquarters of Cornwall County were removed to George Town in May, 1819, by which time the necessary buildings had been constructed.

The inconvenience of having governmental headquarters 40 miles away from the principal northern settlement at Launceston coupled with the loss of the attractive local market for produce provided by the garrison resulted in vigor-



FIG. 7. HEAD OF NAVIGATION ON THE TAMAR RIVER AT LAUNCESTON
SHOWING TEA TREES ALONG THE RIVER AND FORESTED EASTERN TIERS IN BACKGROUND.



FIG. 8. A VIEW ACROSS THE PRINCIPAL RESIDENTIAL AREA
MOST OF LAUNCESTON LIES WITHIN A SMALL AMPHITHEATER OPENING UPON THE TAMAR RIVER.

ous objection to the new arrangement. In 1823, governmental authority for northern Tasmania was returned to Launceston. In the following years George Town lost in population and had little trade while Launceston enjoyed steady growth and an extensive business in wheat and wool shipped down the Tamar in vessels of 250 tons burden. Launceston served as the headquarters for the richest and most extensive agricultural district in the island, and by virtue of its position on a navigable waterway, became the principal focus of trade in the north of Tasmania (Fig. 8).

EARLY RIVALRY BETWEEN HOBART AND LAUNCESTON

Tasmania, with 27 per cent. of Australia's population, was constituted a separate colony from New South Wales in 1825 and Hobart was fixed as the seat of government. The inconvenience and delay involved in governing a colony so far removed from Sydney accounted for the early separation. Considerable op-

position was presented at the time to the selection of Hobart as the capital of the new colony. The rapidly expanding agricultural settlement at Launceston especially objected to the location of government headquarters at the far south end of the island. Others emphasized the disadvantage of keeping the large convict population on the coast where escape was comparatively easy. New Norfolk and Brighton near the head of navigation on the Derwent River were proposed as better sites for the governmental and penal center, but established buildings and facilities at Hobart led to its continued choice. Hobart had a population of 5,000 by 1827 and conducted an increasing trade with Sydney, Great Britain and elsewhere.

Thus, the basic advantages of the Hobart and Launceston sites were early demonstrated, and from the two rival centers population, transportation routes and the various forms of land occupation spread into tributary valleys and lowlands. Sufficient contrast was present

in the potentialities of the two sites to make their later development complementary rather than merely competitive.

RISE OF INDUSTRIAL AND COMMERCIAL ENTERPRISES

One of the early industrial opportunities commanding attention in Tasmania was whaling. In spring the Derwent River is said to have "swarmed with whales." The first bay whaling station was built in 1806, and by 1841 the number had increased to thirty-five. In 1848, there were 37 whalers registered at Hobart employing 1,046 men. Many foreign whalers sought repairs and supplies in the quiet and deep waters of the Derwent. Launceston settlers operated whaling stations at Portland Bay and at Encounter Bay on the Australian mainland.

As an outgrowth of the whaling industry Hobart gained some prominence as a shipbuilding center, an abundance of suitable timber in the Derwent and Huon valleys facilitating that development. An export trade to the mainland was also developed in timber products, for Hobart was the natural shipping point for the rich southern timber region. Tasmanian hardwoods, because of their resistance to marine borers and decay, came into demand for harbor, railway and other construction purposes.

Wool production was early established in Tasmania on a commercial basis, and by 1830 the wool export from the island exceeded that from New South Wales. Generous grants of land by the early governors encouraged the pastoral industry. Massive wool stores of native sandstone were among the first large commercial structures to appear at Hobart and at Launceston (Fig. 9). Early recognition of the paucity of land resources in Tasmania, however, resulted in the migration of some persons with their flocks to Victoria, beginning in 1834. Melbourne itself was founded by such migrants in 1835. South Australia,

likewise, drew immigrants and stock from overcrowded Tasmanian holdings.

During the period 1850-1880 Tasmania exported regularly large quantities of farm produce to Sydney and elsewhere. The California and Australia gold rushes created exceptional markets for Tasmanian agricultural and forest products during the 1850's and 1860's. The rural population of Tasmania became focused during those decades upon the more productive lands tributary to Launceston and Hobart.

By 1880, the mainland states of Australia had greatly expanded their agricultural industries and no longer depended on Tasmania for staple foodstuffs. Fortunately for Tasmania, the loss in agricultural markets was compensated by the discoveries between 1871 and 1882 of important mineral deposits, the exploitation of which provided large sources of income for several decades. The discovery of tin at Waratah in 1871 marked the opening of a new chapter in Tasmania's development. Later discoveries of valuable deposits of copper, zinc, lead, silver and gold were made in the western district at Gormanston, Rosebery, Balfour and elsewhere. Northern Tasmania and Launceston profited most from the mineral development because of direct railway connections with the mining districts.

The formation of the Australian Commonwealth in 1901 rendered more serious a number of problems which already faced Tasmania. Intensified competition with the richer mainland states and the application of Commonwealth economic policies, not recognizing fully the handicaps of the isolated position and the limited resources of Tasmania, have contributed to the static condition which has characterized most forms of economic activity in Tasmania in recent decades.

EMPHASIS ON SPECIALIZED AGRICULTURE

General agriculture and grazing ac-



FIG. 9. OLD GOVERNMENT WAREHOUSES AND RELATED STRUCTURES
ALONG THE HARBOR MARGIN AT HOBART.

tivities in Tasmania have been on the decline for half a century or longer. In the 1850's Tasmania was regarded as the granary of Australia, and important wheat cargoes moved regularly to Sydney. In 1850 Tasmania had more sheep than it has to-day. Physical conditions and other factors have produced systems of agriculture which differ in many respects from those on the mainland.

Small areas are involved in Tasmania in comparison with the large wheat and sheep holdings of other states. Farm lands of good quality are widely scattered, which increases the transportation burden. General farming is characteristic of the island, but emphasis is usually placed on such specialty products as best suit the locality. Sharp and frequent contrasts in agricultural conditions coincide with abrupt changes in physiographic, climatic and soil conditions. Nearly half the island is wholly unoccupied by agriculture of any type. Machinery is much less utilized in Tasmania than in the more extensive farming areas on the mainland. Soil exhaustion and low crop yields reflect poor farm practices and the marginal character of much of the land.

The Midland, a lowland of varied re-

lief and bordered by the abrupt margins of the Western and Eastern tiers, is Tasmania's principal pastoral and agricultural district. Extensive tracts of perennial rye grass and clover with scattered remnants of an open eucalyptus forest cover much of the rolling surface (Fig. 10). Most of Tasmania's wool and mutton is produced in that district. Midland flocks are driven to the bordering uplands after shearing is completed for summer pasturages as indicated by A. G. Lowndes and W. H. Maze in "The Land Utilization Regions of Tasmania."

Oats, lucerne, potatoes and peas are important crops in the flatter portions of the Midland and in areas of fertile soils derived from easily weathered basalt. Scattered small villages with stone houses of colonial design, old English farmsteads, fields bordered by hawthorn hedges, and extensive pasture lands comprise one of the most attractive landscapes in Australia.

Launceston and Hobart, occupying strategic positions on deeply penetrating estuaries to the north and south, command the trade of the Midland. Numerous wool stores are situated in close proximity to the wharves in both centers. Others are located along the



FIG. 10. VIEW TO EAST ACROSS THE TAMAR VALLEY NEAR LAUNCESTON USED FOR SHEEP AND OATS, WITH CHARACTERISTIC RAIL FENCES IN THE FOREGROUND.

railways entering those cities. Since overseas vessels are unable to reach Launceston, wool is lightered to Bell Bay and Beauty Point wharves near the Tamar mouth for foreign shipment. Direct contact with large wool carriers is made at Hobart, where neither tugs nor dredges are required in the operation and maintenance of the port.

Extensive public abattoirs at the margins of Hobart and Launceston process animals from the Midland and other districts for local consumption and for export. Increasing attention is being given to fat lamb production for export because it fits in well with general farming and forage production (Fig. 11). Pig raising, in similar manner, expands with the butter industry.

Ready access to the principal wheat-growing centers of the drier Midland area has likewise facilitated milling operations in both Launceston and Hobart. Hard wheat from South Australia is imported to blend with the softer local varieties.

Also tributary to Launceston is a belt of rich agricultural lands extending from the Tamar River northwest along the coast for a distance of about a hun-

dred miles. The belt is 10 to 15 miles wide, and elevations of as much as 2,000 feet occur where it merges into the Central Plateau along its irregular southerly margin. Extensive tracts of red soils derived from fresh-water deposits and chocolate soils derived from basalt provide the principal bases for agricultural development. Most of the surface is hilly, and deep valleys have been cut through the basalt cover in places exposing poorer soil-forming materials.

The northwest coastal belt was never attractive to graziers because of its heavy forest cover, hence it was occupied only comparatively recently. The many small farm holders specialize in dairying and potato-raising. In 1935, the northwest coast produced potatoes on 30,000 acres of land which constituted five sixths of the land devoted to that crop. Potatoes from Tasmania are extensively used on the mainland and they rank as one of the most important crops in the island. Numerous small ports have arisen along the north coast to provide outlets for farm produce. All the west coast mining communities look to the north coast district for foodstuffs and other supplies, for the western half

of Tasmania is entirely unsuited for agriculture and grazing.

Tasmania has long held the position of the most important producer of export apples in the southern hemisphere. Although the area planted to apples is normally exceeded by those planted to hay, peas, potatoes and oats, the apple is easily the most valuable crop in Tasmania. It is more valuable than the Tasmanian wool clip and approximately equal to the value of all mineral production. Apple production ranks as one of the most successful phases of specialized farming.

About 2,500 growers, 78 per cent. of whom have less than 15 acres of orchard, are engaged in the apple industry according to an official report on "The Tasmanian Apple Industry" by S. F. Limbrick. Probably 15,000 to 18,000 persons or almost 8 per cent. of the population of Tasmania are directly or indirectly dependent for their livelihood upon the industry. The apple industry in Tasmania occupies a position as important relatively as does wheat production in several mainland states. In 1935, the bearing acreage of apples amounted to 23,400 or slightly more



FIG. 11. APPLE ORCHARDS ALONG THE LOWER TAMAR RIVER
MARSH GRASS COVERS THE MUD FLATS BORDERING THE WATERWAY.

Local advantages of climate and soil in conjunction with the ability to provide fruit at a season opposite to the time of harvest in the northern hemisphere led to the beginning of specialized output of export apples about 50 years ago, especially in the Derwent and Huon valleys (Fig. 13). More recently production has spread to the Tasman Peninsula, Bagdad and Spring Bay districts in the south, as well as to the Tamar, Latrobe, Lilydale and Scottsdale districts in the north (Fig. 12). Many areas too rough for other forms of agriculture have proven to be excellent for orchards, while the higher slopes remain in eucalyptus forest.

than two thirds the total orchard plantings. During the past twenty years no large increase has taken place in apple plantings, which suggests that the industry has reached its economic limit under present conditions. However, large tracts of land remain which are suitable for apples should increased demands arise.

Shipments of Tasmanian apples to overseas markets have fluctuated between two and one half and three million cases in recent years. Hobart is the principal center of that trade, but Beauty Point and Bell Bay on the lower Tamar River handle increasing quantities of fruit grown in the northern dis-



**FIG. 12. CHARACTERISTIC PASTURE LAND NEAR LAUNCESTON
WITH SCATTERED EUCALYPTUS TREES.**



**FIG. 13. THE KANGAROO RIVER VALLEY NEAR HOBART
DEVOTED TO APRICOTS, OATS AND PASTURE, WHILE BORDERING UPLANDS REMAIN IN TIMBER.**

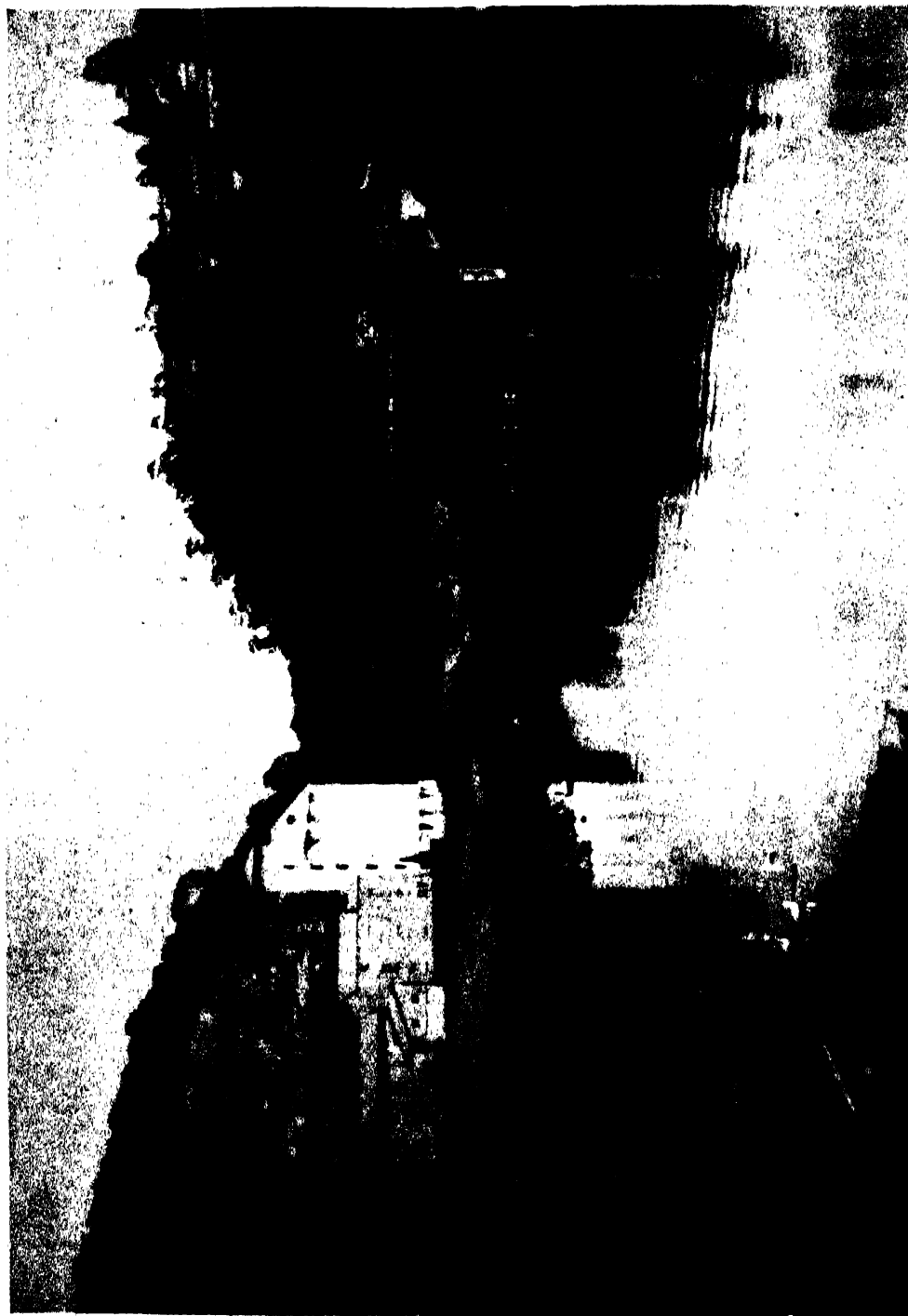


FIG. 14. GORGE OF SOUTH ESK RIVER AT LAUNCESTON

tricts. The shipping season for overseas export is relatively short, beginning in late February or early March and continuing until the middle of June. Apples are received at the export wharves by rail, river steamer and highway vehicles. As many as 300,000 cases may be shipped in a single week and on a peak day 100,000 cases may be handled over the wharves.

During the apple season many large vessels not normally calling at Tasmanian ports are diverted for that traffic. Interstate shipments are carried in smaller vessels plying regularly in coastwise trade, without refrigeration and over a longer season. They amount to about 1,250,000 cases annually. New South Wales and Queensland are the principal consumers of Tasmanian apples entering interstate trade, while the United Kingdom, Germany, Scandinavia, Holland and France have been the principal buyers overseas. In 1935, overseas markets took 72 per cent. of the shipments and interstate trade 28 per cent.

Pears are grown throughout the apple districts and occupy about 2,000 acres. Apricots, plums, cherries, peaches and quinces together occupy another 2,000 acres. Strawberries, raspberries, currants and other small fruits occupy 2,600 acres usually in close association with orchard districts. Preserved fruits, jellies and fruit pulp are important items moving in interstate and foreign trade from Tasmania.

HYDRO-ELECTRIC POWER STIMULATES MANUFACTURING

A half century or more ago small manufacturing industries were distributed among most of the settlements in Tasmania. Small breweries, tanneries, flour mills, farm implement shops, soap and candle factories, boot shops, basket works and wood-working shops utilized local raw materials and served home markets. The provision of railways tended to consolidate the many scattered and small plants principally in Hobart and Launceston. After the Commonwealth was established in 1901 the rise



FIG. 15. THE EXTENSIVE ELECTROLYTIC ZINC WORKS AT HOBART
ITS PRIVATE DOCK IS SHOWN TO THE LEFT ACROSS THE DERWENT RIVER.



FIG. 16. A PORTION OF THE HOBART WATERFRONT BESIDE THE LARGE JAM FACTORY
MANY SMALL BOATS OF THE TYPES SHOWN ENGAGE IN LOCAL COMMERCE THROUGHOUT THE DERWENT RIVER DISTRICT AS WELL AS IN OTHER
PARTS OF TASMANIA.

of large-scale manufacturing plants on the mainland brought about a decline of most forms of manufacturing in Tasmania.

During the past two decades, however, Tasmania has made important progress along manufactural lines largely as a result of the provision of abundant and cheap hydro-electric power. More than 90 per cent. of the power now used in industries is hydro-electric energy. Hobart and Launceston have been vitalized by the new source of power. While Tasmania compared unfavorably with several other states in the possession of usable coal, it now boasts of the best supply of hydro-electric power in Australia. The utilization of that valuable resource has only begun and much more power can be developed as soon as it is demanded. There is the possibility that hydro-electric power may in the future provide the means of attracting many more industries to Tasmania, permit a further expansion of population, and rejuvenate agriculture by the creation of larger local markets. But cheap electrical power has not yet attracted a sufficient number of new industries to bring about a great change in economic conditions in Tasmania. Other obstacles, such as limited local markets, high transportation costs and restricted supplies of many raw materials, discourage extensive manufactural development.

The Central Plateau or Lake District is the principal source of hydro-electric power and the outstanding physiographic feature of Tasmania. It consists of an undulating diabase plateau 3,000 to 4,000 feet above sea-level and sloping gently southeastward. On the north and northeast precipitous escarpments called the Great Western Tiers define its border; on the west its margin is deeply furrowed by west-flowing rivers forming extremely rugged mountain ranges; and on the south the Derwent River and its tributaries have converted

the margin of the plateau into a jumbled mass of valleys and hills. A rainfall of 30 to 60 inches annually characterizes much of the upland surface. Most of the lakes occupy shallow basins and are bordered by insignificant uplands. Most of the plateau is covered by stunted eucalyptus forest and coarse grass, but dense growths of evergreen beech and horizontal brush characterize the west margin.

In 1908, the Tasmanian Government granted a private company permission to develop water power at Great Lake for the treatment of complex zinc ores by electrolysis. After the work was well advanced the company met financial reverses, and, in 1914, the project was acquired by the government. By 1916, the work was completed and power was delivered to Hobart. Thus was begun the extensive modern state hydro-electric system in Tasmania (Fig. 1).

Storage for the Great Lake power project consists of the natural lake, the capacity of which was increased by means of a 40-foot multiple-arch dam to 1,150,000 acre-feet. The surface of the lake (60 square miles) is 3,350 feet above sea-level and 1,125 feet above the power house at Waddamana. An additional water shed of 107 square miles was added to the Great Lake water shed of 153 square miles by diversion of the headwaters of the neighboring Ouse River. Installed capacity of the Waddamana power station is 66,000 horse power. High-voltage transmission lines extend to Hobart (63 miles distant), to Launceston (53 miles) and to Railton (59 miles). Smaller distribution lines radiate from those centers. Most parts of Tasmania lie within a 90-mile radius of the Great Lake power plant, thus greatly facilitating the distribution of power.

Several smaller power sites have been developed by the Hydro-electric Commission, and their output is fed into the state-wide system of power lines. Lake

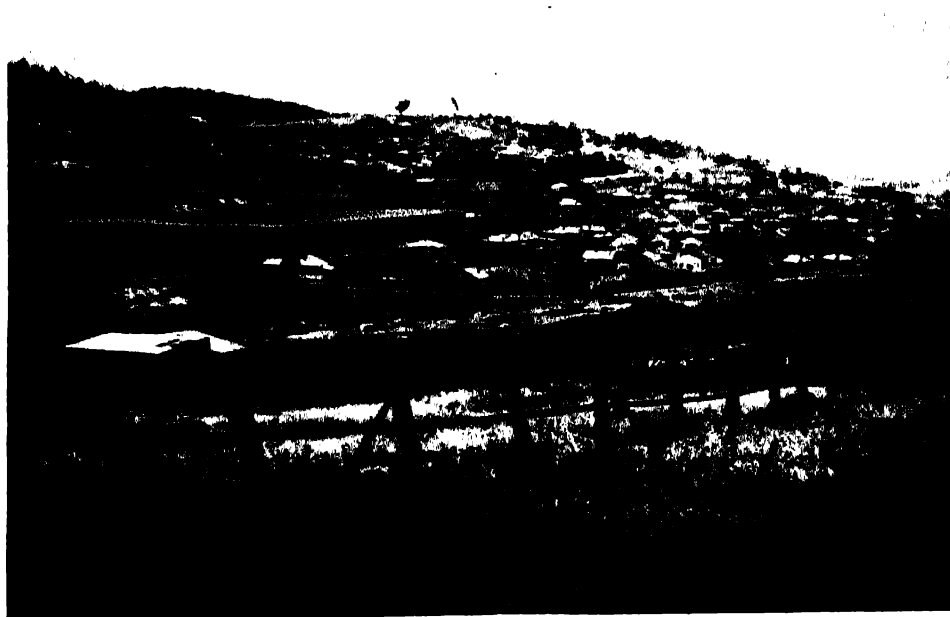


FIG. 17. LARGE MODERN WOOLEN MILL AT SOUTH MARGIN OF LAUNCESTON



FIG. 18. BRISBANE STREET IN THE COMMERCIAL CORE OF LAUNCESTON

St. Clair is the source of water for developing 21,000 horse-power at Tarraleah, and it is claimed to afford an ultimate capacity of 126,000 horse-power. The River Shannon contributes 15,000 horse-power to the state system.

Several privately owned power supplies have been developed in the west coast region to serve mining interests. For example, mines at Gormanston and smelters near Queenstown obtain 10,000 horse-power from the Lake Margaret development. The Lake Margaret scheme has a catchment area of only eight square miles, but a well-distributed rainfall of 145 inches and an effective head of 1,150 feet for the turbines are highly favorable factors. Mines at Waratah also have small independent hydro-electric sources. A number of cities operate small water power plants along the north coast. Launceston has one of the oldest installations in the Commonwealth in the South Esk River gorge near the city (Fig. 14).

PRINCIPAL INDUSTRIES ATTRACTED BY CHEAP POWER

The electrolytic zinc refinery, established in 1917 at Hobart, is the largest and most important manufacturing establishment in Tasmania (Fig. 15). It utilizes 45,000 continuous horse-power drawn from the state hydro-electric system. Some 800 men are employed in the plant, which operates on a continuous basis. The daily capacity of the works is 150 to 200 tons of electrolytic zinc, most of which is cast into 50-pound slabs and is shipped by water to world markets. Small amounts of rolled zinc and other products are also manufactured. Fuels (coal and coke) are imported by water from New South Wales. An important by-product of the plant is sulfuric acid, which is used to treat phosphate rock obtained from Nauru and Ocean islands. About 20,000 tons of superphosphate fertilizer are produced annually, which amount is suffi-

cient to meet Tasmania's needs. The recovery of sulfur by-products from ore-roasting processes is of great national significance, for other sources are unavailable in Australia. Contact with the state railway system makes possible the direct distribution of fertilizer materials to most developed parts of the island. At some future time atmospheric nitrogen may be fixed with Tasman hydro-electric power, thus providing Australia with a second essential fertilizer material.

The zinc concentrates treated at Hobart are obtained from Broken Hill, N.S.W., mines after roasting plants at Port Pirie, Wallaroo and Adelaide, S.A., and Cockle Creek, N.S.W., have extracted most of the sulfur. Vessels returning from Hobart carry residue ore materials containing small quantities of lead, silver, cadmium and copper for final treatment at Port Pirie. Although the zinc plant is situated 4 miles above Hobart and 16 miles from the entrance to the Derwent estuary, a natural depth of more than 30 feet of water is available at the company docks. Zinc ores from mines at Rosebery and other centers on the west coast of Tasmania also have been treated at various times. Those ores are moved by rail to Zeshan for milling and roasting, thence to Strahan for shipment by water to Hobart. Their complex nature, low grade and great depth have combined to make extraction uneconomical in recent years. Launceston at one time was a smelting center for ores obtained from scattered mines in the northeast portion of the island. Metal mining is on the wane in Tasmania, but it was an important factor in the island's development especially during the period 1880-1910.

Another industry, situated along the estuary margin 12 miles south of Hobart, which owes its establishment to cheap hydro-electric power, and using 4,500 horse-power, is the carbide works at Electra. Large portions of the

carbide and electrode requirements of Australia are manufactured in that modern industrial town. Raw materials are quarried locally and the plant has direct ocean shipping facilities.

A third major new industrial plant at Hobart, owing its establishment to favorable power conditions, but also to suitable climatic, transportation, labor and marketing conditions, is the large confectionery and chocolate factory at Claremont, 8 miles north of Hobart. The plant is situated on a peninsula jutting into the Derwent River and it is served by a private wharf. An attractive residential suburb has been developed on the adjoining mainland. The confectionery plant is a good example of the type of branch plants recently established in Australia by British manufacturers.

Two large jam and fruit-canning plants, one situated on the waterfront at Hobart and the other at Newtown (a northern suburb), provide an outlet for large quantities of fruits and berries grown in the vicinity (Fig. 16). Preserved fruits and jams are one of the important export items to Great Britain from Hobart. The focal position of Hobart with respect to numerous valleys adapted to fruit-growing facilitates large-scale preparation of highly perishable fruits and berries. Both water and land types of transport serve in the assembly of the fruits from scattered small farm units.

Plans for the establishment in the vicinity of Hobart of a large paper-manufacturing plant are well matured. Australia has long been dependent upon Canada for most types of paper because of her inability to make satisfactory grades from eucalyptus and other native hard woods. It appears that suitable processes have now been developed, and Tasmania, with considerable forest land resources, cheap power and water transport, may become an important source of paper for the entire Commonwealth. A

second plant is projected for the north coast at Burnie.

At Launceston two important woolen mills utilize hydro-electric power but also credit favorable climatic and labor conditions for their establishment. One mill is situated in the elevated southern residential district (Fig. 17), while the other is located on the Tamar River lowland near the shipping docks and in close proximity to wool warehouses and northern residential suburbs. Blankets, velours, tweeds and knitting wools are manufactured for Australian markets. Both mills are branch plants of large British textile manufacturers.

Several ceramic plants in Launceston utilizing local clays find outlet for their products in Tasmania and in mainland markets. Native blackwood (*Acacia melanoxylon*) is used in the manufacture of fine furniture and novelties which have become as characteristic of that state as are the Mulga wood products of the mainland. Being the center of the Tasmanian railway system the principal repair shops are located at Launceston.

At Railton, to the west of Launceston, is a cement plant utilizing local raw materials and serving markets in Tasmania and on the adjacent mainland. A quarter million tons of limestone are quarried annually at Melrose and shipped through Devonport for blast furnace use at Newcastle and Port Kembla, N.S.W. Large quantities of electrical power are utilized by both of those industries.

Most of Tasmania's coal mines are situated in the Fingal district about 40 miles southeast of Launceston. As many as 125,000 tons are produced annually or a sufficient amount to serve most of Tasmania's needs. The railways are the principal consumer utilizing nearly half the annual output. Small amounts of coal are imported for the manufacture of gas and for metallurgical establishments. Hydro-electric power is made

available even to the towns in the coal-producing district, thus illustrating its wide distribution and its strong competitive ability.

GROWING IMPORTANCE OF THE TOURIST INDUSTRY

The economic value of the growing tourist trade is recognized clearly in Tasmania. An active government tourist bureau maintains offices in all the capital cities of the mainland to promote travel to the island. Many of the conditions discouraging to agriculture and industry are favorable to the tourist trade. The generally irregular surface with altitudes up to 5,000 feet, the little altered character of much of the island with large tracts scarcely inhabited, the succession of beaches interspersed with rugged promontories, the rich native vegetation, the scores of lakes and streams, the pleasantly cool and moist climate, the variety of agricultural landscapes ranging from expansive sheep stations to intensively cultivated horticultural communities, restful towns and small cities with architectural types reminiscent of old England and a rich historical background recalled by structures still in evidence everywhere are some of the recreational attractions afforded by Tasmania. The island is only 16 hours by steamer from Melbourne and 44 hours from Sydney, thus attracting large numbers of persons even during short holiday periods. Most of the tourists come from the capital cities of the mainland, and they find the Hobart summer a pleasant relief (Fig. 18). The Christmas-New Year's holiday period marks the height of the summer tourist season. Winter sports are also being stimulated during June, July and August in an attempt to spread the tourist season over the entire year. The small size of the island and the extension of motor roads to supplement existing

railways enable the visitor to see a wide variety of landscapes in a relatively brief period. In addition to the long-established midland route between Launceston and Hobart new scenic highways now extend along the east coast and over the central plateau. A national reserve of about 200 square miles and including mountain-bordered Lake St. Clair is generally recognized as the most scenic attraction in the island. Mountains reaching elevations of 4,000 to 5,000 feet, dense forests, deep canyons, waterfalls and lakes attract many visitors. Winter sports as well as summer attractions are available there.

CONCLUSION

Whether due to luck or foresight the early selection of Hobart and Launceston as the principal centers of occupation in Tasmania was fully justified by the later rise to importance of those centers. Although Tasmania's population is more evenly distributed geographically than that of any other Australian state the dominance of the Hobart and Launceston agglomerations is the outstanding characteristic of population distribution.

Although an integral part of the Australian Commonwealth, Tasmania comprises a somewhat small and isolated section with a lesser supply of good land and other natural resources to hold its slowly expanding population. Greater opportunities on the mainland attract Tasmanian youth as well as foreign capital. Tasmania continues chiefly to export raw materials and to import manufactures, although the development of cheap hydro-electric power has brought about a partial reversal of those movements. In some phases of specialized agriculture and in the growing tourist industry Tasmania finds important sources of income and a basis for friendly cooperation with other states of the Commonwealth.

THE FUTURE OF THE SOCIAL SCIENCES

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I

THE question of what can be expected from the social sciences always comes to the front in times like the present. The reason for this interest in the future possibilities of sciences of human relation is, I suppose, obvious. Every one agrees that whatever other troubles the advancement of science may have brought in its wake, it has released us from some age-long fears and insecurities. The natural sciences have undoubtedly given us a large measure of control over many of our traditional enemies, although we may not always exercise this power.

Even when we can't do anything directly about averting natural events, science is still invaluable in two principal ways: First, science forewarns us of certain events and thus enables us to avoid their more serious consequences. If rain is predicted we carry an umbrella. Ships are warned that a hurricane is likely to follow a certain path. We may protect ourselves from certain diseases by proper inoculations; and so forth. In the second place, the mere possession of scientific knowledge and scientific habits of thought regarding the natural universe relieves us from a world of fears, rages and other unpleasant dissipations of energy. Scientific knowledge operates as a sort of mental hygiene in the fields where it is applied. If the morning paper reports an earthquake, an eclipse, a storm or a flood, these events are immediately referred to their proper place in the framework of science, in which their explanation, i.e., their relationship to other events, has already been worked out. Hence each new event of this char-

acter calls for very little, if any, "mental" or "emotional" strain upon the organism so far as our intellectual adjustment to it as an event is concerned.

Political and social upheavals, on the other hand, such as wars, revolutions and crime are to most people a matter of shock and much personal recrimination and other emotionalism. The point is perhaps best illustrated by a recent cartoon showing two old gentlemen with obviously high blood pressure engaged in animated conversation. The venerable wife of one of them appears and says, "Remember now, the doctor says you must not talk about Mr. Roosevelt." The nervous condition of most commentators on the European situation is not, I think, conducive either to the clearest kind of analysis of that upheaval or to good digestion. Floods, hurricanes and crop failures also worry us, but we take a very different attitude toward them.

It is not surprising, therefore, that man should have become increasingly interested in the question as to whether this same tool called science might do as much for him as regards his social predicaments. But immediately certain apparently insurmountable obstacles present themselves, which send all but the hardiest scurrying for shelter in the tents and pagodas of the traditional doctors of social ills—the magician, the soothsayer, the priest and the politician, with their lore. What are these obstacles to the development of an effective social science? Are they as insurmountable as they seem?

II

In order to avoid the accusation that I am merely attacking a straw man by

selecting only the more silly of the objections that have been urged against the possibilities of a science of human relations, I shall deal instead with those that are held by responsible scientists themselves. That is, I shall omit entirely certain metaphysical questions which have traditionally beclouded the subject, such as the question of free will, God, etc. What I am about to say will be quite compatible with any view one wishes to hold on these subjects. In short, I do not think they are questions of scientific importance. Posit, if you like, free will not only for man but for all other things in nature. All I am interested in at present is to point out the great regularity and predictability with which men will things. The same may be said for God. He is clearly a being with remarkably and demonstrably regular habits. It is this regularity and predictability of the will of both men and gods that is of interest to science.

There are, on the other hand, the doubts which are advanced by competent scientists, such as Julian Huxley. In a recent address before the American Association for the Advancement of Science under the title of "Science Natural and Social,"¹ he discusses what seems to him to be major obstacles in the path of the social sciences. It is true that he already leans heavily toward the position of the present paper. The reservations which he feels are inherent in the nature of the subject-matter and the situation that confronts the social scientists are therefore deserving of the highest respect and most careful consideration. Yet after such consideration I do not feel that these obstacles are of the fundamental nature that Mr. Huxley is inclined to assign to them. Let us examine the case.

Mr. Huxley begins with somewhat the same question with which I started: He says:

¹ SCIENTIFIC MONTHLY, January, 1940.

The question immediately poses itself as to why the emergence of social science into large-scale and efficient operations has been so long delayed. The triumphs of natural science both in discovering radically new knowledge and in applying it practically to satisfy human needs have been so spectacular and so fruitful that it would seem natural and obvious to extend the same methods to the field of social phenomena.

The answer is a very simple one: the methods are *not* the same. The scientific spirit remains unaltered whether it is contemplating a nebula or a baby, a field of wheat or a trades union. But the methodology of social science is inevitably different from that of natural science. It is different and must be different from one basic reason—the investigator is inside instead of outside his material. Man can not investigate man by the same methods by which he investigates external nature. He can use the methods of natural science to investigate certain aspects of man—the structure and working of his body, for instance, or the mode of his heredity; but that is because these are shared with other organisms and because they are partial aspects which can be readily externalized. But when he starts investigating human motive, his own motives are involved; when he studies human society, he is himself part of a social structure.

What consequences does this basic difference imply? In the first place, man must here be his own guinea pig. But this is impossible in the strict sense, for he is unable to make fully controlled experiments [pp. 6, 7].

The basic difference between the social and the physical sciences is here alleged to be that in social science "the investigator is inside instead of outside his material." This is incidentally one of the most frequently heard clichés, which is supposed to be so self-evident as to require no analysis. Will it bear analysis? I think not at all. It turns out on examination to be little more than a figure of speech designed to call attention to the danger of biased observations and interpretation—a danger which is present in all science and which can in any case only be circumvented or reduced through the use of scientific instruments and methods of procedure which are part of scientific training in *any* field.

When an anthropologist goes to a remote savage tribe to study its social behavior, why is he any more inside his

material than when he studies a colony of anthropoid apes, beavers, ants, the white rats in the laboratory, an ecological distribution of plants or, for that matter, the weather, the tides or the solar system? At what point exactly in this series does the mysterious transition from outside to inside of one's material take place? Nor do I admit that I have to go to a distant land and study savages in order to make my point. I can give as objective and checkable a report on some of the social events that take place in the community where I now live as I can on the meteorological events that take place there. Both involve problems of observing and reporting accurately the events in which I am interested. In doing this, I need to use instruments as far as possible to sharpen my observation, to check it and to report it accurately. These instruments do not exist ready-made in any field. They have to be invented. They may be quite elementary as yet in much social investigation, consisting of little more than a pencil, a schedule, a standardized test or the recording of an interview. But we also have at our command the movie camera with sound equipment with which social behavior can be observed in its cruder aspects with the same accuracy as any physical behavior is observed. When I use these instruments I am no more "inside" my material than when I photograph an eclipse.

The invention of units and instruments with which to systematize observation is part of the scientific task in all fields. Neither calories nor calorimeters came ready-made in the phenomena of physics. They have to be invented to apply to the behavior in question, just as units of income or standard of living and scales for measuring them have to be invented. I am not making light of the difficulties involved in inventing either such units or appropriate instruments of scientific observation. Nor would I minimize the problems of inter-

preting the data which I observe. But here again I have at my disposal the same rules of logic, statistics and scientific method that I apply to observations of physical events.

To be sure, Mr. Huxley makes the concession that we can use the methods of natural science "to investigate certain aspects of man—the structure and working of his body, for instance, or the mode of his heredity." But clearly these are not the proper subject-matter of the social sciences at all. Huxley appears here to be under the common misapprehension that anything pertaining to man is necessarily subject-matter for social science. It hardly needs to be remarked that man, as such, is as much the subject-matter of biology, physiology, chemistry or physics as he is the subject-matter of the social sciences. Only certain aspects of man's behavior is the subject-matter of the social sciences. What some of the more difficult of those aspects are in Mr. Huxley's opinion is betrayed in the very next statement: "But where he [the social scientist] starts investigating human motives," he says, "his own motives are involved; when he studies human society, he is himself a part of a social structure." And what is supposed to be so important about this? "In the first place," says Mr. Huxley, "man must be his own guinea pig." He then proceeds to repeat the familiar objection about the difficulty of controlled experiment in the social sciences.

A great many able people apparently share Mr. Huxley's feelings regarding the mysteriousness, the uniqueness and the inscrutability of human motives. To begin with, we may note that motives are not directly observed phenomena at all, but are inferences from behavior. How do we, as a matter of fact, determine them right now? One common method is to assemble twelve good men and true, farmers, bookkeepers, salesmen—anybody that comes to hand, subject them to a mass of evidence regard-

ing the circumstances of a certain event, after which the judge charges them to determine whether "the motive" of one of the principals in the affair was fraudulent, felonious, malicious, etc., or not. And how do these worthy citizens proceed with the assignment? They draw on their own lives and experience, on what their random and unsystematic observation of human behavior in the past has taught them, plus what they may have learned from folklore, the Bible and perhaps books on history, psychology and psychoanalysis. Against this background they lay the testimony, and on this basis they decide "the" motive. The procedure is far from perfect, as we know, and it is not claiming too much, I believe, to assert that scientists properly trained for this kind of work would make much fewer mistakes. But we think highly enough of even the ability of the lay jury to determine human motivation to make their decision the basis of life or death for free citizens.

"When the scientist studies human motives," says Huxley, "his own motives are involved; when he studies human society he is himself a part of a social structure." I submit that the only motive of a true scientist in trying to determine the motive of an action is to find the true answer to the question, and that is the only motive with which scientists both physical and social are concerned, *as scientists*. In short, the motive of the sociologist and the physicist are exactly the same in the face of a scientific problem. *The motive is to find an answer that meets the requirements of a scientific answer.* The fact that the social scientist has always been a part of a social structure is no more a handicap to its objective study than is the fact that he is also part of the physical universe which he studies. Error, corruption and bias, conscious and unconscious, are constant dangers inherent in *all* observation, both physical and social. The training of a scientist con-

sists of developing in him the traits of character as well as technical skill, and the use of corrective instruments to reduce to a minimum the errors that beset our unchecked senses in every field.

With respect to the difficulty of laboratory experimentation in the social sciences, we may grant a great deal to Mr. Huxley's point, especially as regards comparisons with such sciences as chemistry, physics and biology. But the difficulty is by no means insuperable. Extensive sociological experiments involving laboratory observations of children have been and are being carried on. Motion picture and sound recording of these experiments, furthermore, permit their detailed and repeated study. Nor are experiments on actual communities impossible. Stuart C. Dodd, for example, carefully measured with instruments especially constructed for the purpose the hygienic status of a group of isolated Syrian villages.² He divided the villages into two samples for experimental purposes. One sample was then subjected to a two-year period of hygienic education through an itinerant clinic. At the end of this period the hygienic status of the two samples, consisting of one experimental village and three controls, were again carefully measured. The comparison of the scores of the experimental and the control villages yielded a reliable measure of the results of the program of health education. It is true that in this case the absence of contact of these villages with the influences of the outside world was a principal condition of the success of the experiment. But the study will stand for a long time as a model of scientific proficiency in the care with which the measuring instruments were prepared, tested and applied, as well as in the attention to problems of sampling and probable errors.

Finally, it should be pointed out that

² "A Controlled Experiment on Rural Hygiene in Syria." Oxford University Press, 1934.

the matter of laboratory control varies greatly with different sciences. The solar system has never been brought into any laboratory. Astronomical laboratories do contain very ingenious symbolic and mechanical representations of the astronomical aspects of that system and remarkable instruments for observing it. These every science must unquestionably develop. Beyond this, the question of laboratory conditions becomes one of convenience and mechanical ingenuity. Statistical devices which permit the observation of two or more variables while the influence of others are held constant, in the sense of their influence being measured and allowed for, are already in common use. In justice to Mr. Huxley, it should be said that he recognizes this fact. In dealing with the multiplicity of causation in social situations he says:

In regard to multiple causation we may look forward to an extended use of techniques of mathematical correlation. These have already been developed to a high pitch for dealing with problems of multiple causation in physical science, and special methods have been worked out by Spearman and his school for dealing with psychological questions. The use of probability methods is also indicated. Here again these have been developed to a high pitch for use in natural science. . . . In one field, that of the straw ballot, it is developing such uncanny accuracy that it is infringing upon practical politics [pp. 8, 9].

In short, we may say with respect to laboratory experimentation in the social sciences, first, that it is by no means impossible, and secondly, that it is not entirely essential because the same results can be secured by statistical methods.

III

We have now considered two very common and apparently crucial differences between the social and the physical sciences, namely, (1) the notion that in the former the scientist is in some mysterious way part of his data and (2) the difficulty of laboratory experimentation. Mr. Huxley goes on to say:

Finally, there comes the most fundamental difference of all. Values are deliberately excluded from the purview of natural science: values and all that they connote of motive, emotion, qualitative hierarchy and the rest constitute some of the most important data with which the social scientist must deal. But how can science deal with them? Science must aim at quantitative treatment: how can it deal with the irreducible absolutes of quality? Science must be morally neutral and dispassionate: how can the social scientist handle the ethical bases of morality, the motives of passion?

Let us be frank with ourselves. There is a sense in which, because of the qualitative difference between its data and those of natural science, social science can never become fully and vigorously scientific. To understand and describe a system involving values is impossible without some judgment of values, and still more impossible without such value-judgments as the other scientific function, that of control [p. 8].

These sentiments have been so widely and uncritically repeated that they are accepted by a great many able people, including scientists, as in the nature of self-evident facts. It requires, therefore, a certain temerity to express the opinion that there is little foundation for these assumptions. I believe they owe their prevalence to the prestige of the sources that have repeated them and the frequency and emotionality of their repetition, rather than to their tenability in the light of critical analysis.

Let us consider this mysterious word "value." John Dewey in one of his recent publications gives the following account of how it happens that the problem of value arose as a separate problem:

The elimination of value-conceptions from the science of non-human phenomena is, from a historical point of view, comparatively recent. For centuries, nature was supposed to be what it is because of the presence within it of *ends*. In their very capacity as ends they represented complete or *perfect* Being. All natural changes were believed to be striving to actualise these ends as the goals toward which they moved by their own nature. Classic philosophy identified *ens*, *verum*, and *bonum*, and the identification was taken to be an expression of the constitution of nature as the object of natural science. In such a context there was no call and no place for any *separate* problem of valuation and values, since what are now termed values were taken to be integrally incorporated in the very

structure of the world. But when teleological considerations were eliminated from one natural science after another, and finally from the sciences of physiology and biology, the problem of value arose as a separate problem.³

The principal thing to note in this statement is that the problems of value, ends and purposes were once also prominent in the physical sciences. Most of them now manage to get along without the concept, in the sense here under discussion. We manage to keep the matter alive in the social sciences by a quaint habit of speech by which the verb "valuing," meaning any discriminatory or selective behavior, is converted into a noun called "values." We then go hunting for the things denoted by this noun. But there are no such things. There are only the valuating activities we started with. What was said above about "motives" applies with equal validity to values. They are clearly inferences from behavior. That is, we say a thing *has* value or *is* a value when people behave toward it so as to retain or increase their possession of it. It may be economic goods and services, political office, a mate, graduation, prestige, a clear conscience or anything you please. Now since valuations or values are empirically observable patterns of behavior, they may be studied as such, by the same general techniques as we use to study other behavior.

As a matter of fact, everybody is more or less regularly engaged in such study of other people's values. It is quite essential to any kind of satisfactory living in any community. We try to find out as soon as possible what the values of our neighbors are. How do we find out? We observe their behavior, including their verbal behavior, listen to what other people say about them, what they spend their money for, how they vote, whether they go to church and a hundred other things. On a more formal and scientific level, straw votes on men

and issues are taken to reflect the values of large groups. Economists, of course, have been studying for years certain kinds of evaluations of men through the medium of prices. There appears to be no reason why values should not be studied as objectively as any other phenomena, for they are an inseparable part of behavior. The conditions under which certain values arise (*i.e.*, the conditions under which certain kinds of valuating behavior take place) and the effects of "the existence of certain values" (as we say) in given situations are precisely what the social sciences must study and what they are studying. These values or valuating behaviors, like all other behavior, are to be observed, classified, interpreted and generalized by the accepted techniques of scientific procedure. Whence then derives this notion that they represent a unique and insurmountable obstacle in the social sciences?

I have suggested that the basic reason is a confusion of words with things—a very common source of confusion in the social sciences. The point is well illustrated in the passage I have quoted from Huxley. "Science must be morally neutral and dispassionate," he cries: "How can the social scientist handle the ethical bases of morality, the motives of passion?" Well, what kind of "handling" of these things does the scientific quest call for? Huxley says, I think correctly, that science must be morally neutral and dispassionate. Is it really impossible for a trained social scientist to go into a community and give a true report on what are the ethical bases and the morals of a community? The question seems to me quite preposterous. The laws, the mores, the customs, the etiquette, the education and the general behavior of people have been so studied repeatedly and are surely as amenable to such study as is a study of the social life of ants and termites. It is true that the reliability and validity of the results of such study depend upon

³ "Theory of Valuation," *International Encyclopedia of Unified Science* (1939), pp. 2, 3.

the technique with which they are carried out. But that is equally true of the observation and reporting of observation in the other sciences. Of course, it makes a difference, as we have seen, whether a poll is carried out by the technique of a Gallup or a *Literary Digest*. I am not here minimizing the difficulties of objective study of human behavior, a point to which I shall return later. I am saying that if we take the proper precautions of the kind that constitute scientific training in any field, including the development of instruments to facilitate these precautions, there appears to be no reason why a reliable report of the ethical codes and practices of people can not be determined as has indeed repeatedly been done by anthropologists and sociologists in recent decades.

It will perhaps be objected that I have avoided the statement that "to understand and describe a system involving values is impossible without some judgment of values." The only judgment of values I am compelled to make in studying the mores of a community is the judgment of what behavior is relevant to my problem. That is a value judgment which every scientist has to make regardless of what he is studying. If Huxley's statement that "to understand and describe a system of values is impossible without some judgment of values" means that I must also appraise the things I observe from the standpoint of my own moral standards, then his statement is certainly preposterously false. I can certainly report the bald fact that a certain tribe kills its aged and eats them without saying one word about the goodness or badness of that practice according to my own standards, or allowing these standards of mine to prevent me from giving an accurate report of the facts mentioned. The only value judgment which any properly trained scientist makes about his data are judgments regarding their relevance

to his problem, the weight to be assigned to each aspect and the general interpretation to be made of the observed events. These are problems which no scientist can escape, and they are not at all unique or insuperable in the social sciences.

It is interesting to note that Huxley himself, after having made the sweeping and eloquent statements I have quoted, rather comes around in the very next paragraph to the viewpoint I have taken. Referring to the objection which I quoted a moment ago, he says: "However, this is not quite so serious as at first sight appears. Even in natural science, regarded as pure knowledge, one value-judgment is implicit—*belief in the value of truth*." This value judgment, together with the value judgments as to what facts and methods are relevant to this end, are, as I have already said, undoubtedly involved in the social sciences. But they are no less involved also in all other sciences.

There remains, therefore, only the question as to whether the *application* of the knowledge which constitutes, or would constitute, a mature social science, does not involve value judgments of a type which the other sciences do not require. That the application of scientific knowledge (*i.e.*, problems of social control) involve value judgments is obvious. The only question is whether this is a problem peculiar to the social sciences. Here again Huxley concludes, and I think correctly, that this problem is equally present in the other sciences. After we know how to produce dynamite and what it will do, there remains the question: Shall we drop it from airplanes to destroy cathedrals and cities, or shall we use it to build roads through the mountains? After we know the effects of certain drugs and gases, the question still remains: Shall we use them to alleviate pain and prevent disease or shall we use them to destroy helpless and harmless populations? There is certainly nothing in the well-developed sciences

of chemistry or physics which answers these questions. Neither is it, in my opinion, the business of the social sciences to answer directly the question of what form of government we should have, what our treatment of other races should be, whether we should tolerate or persecute certain religious groups, whether and to what degree civil liberties should be maintained, and a multitude of other questions which agitate us. What, then, are social scientists for and what should they be able to do?

Broadly speaking, it is the business of social scientists to be able to predict with high probability the social weather, just as meteorologists predict sunshine and storm. More specifically, social scientists should be able to say what is likely to happen socially under stated conditions. A competent economist or political scientist should be able to devise, for example, a tax program for a given country which will yield with high probability a certain revenue and which will fall in whatever desired degrees upon each of the income groups of the area concerned. Social scientists should be able to state also what will be the effect of the application of this program upon income, investments, consumption, production and the outcome of the next election. Having devised such a tax program and clearly specified what it will do, it is not the business of the social scientist any more than it is the business of any other citizens to secure the adoption or defeat of such a program. In the same way competent sociologists, educators or psychologists should be able to advise a parent as to the most convenient way of converting his son into an Al Capone as well as how to convert the boy into an approved citizen, according to what is desired.

My point is that no science tells us what to do with the knowledge that constitutes the science. Science only provides a car and a chauffeur for us. It does not directly, as science, tell us

where to drive. The car and the chauffeur will take us into the ditch, over the precipice, against a stone wall or into the highlands of age-long human aspirations with equal efficiency. If we agree as to where we want to go and tell the driver of merely the goal of our journey he should be able to take us there by any one of a number of possible routes the costs and conditions of each of which the scientist should be able to explain to us. When these alternatives have been made clear it is also a proper function of the scientist to devise the quickest and most reliable instrument for detecting the wishes of his passengers. But except in his capacity as one of the passengers, the scientist who serves as navigator and chauffeur has no scientific privilege or duty to tell the rest of the passengers what they should want. There is nothing in either physical or social science which answers this question. Confusion on this point is, I think, the main reason for the common delusion that the social sciences, at least, must make value judgments of this kind.⁴

It does not follow, of course, that science by virtue of its true function, as outlined above, may not be of the utmost importance in helping people to decide intelligently what they want. As a matter of fact, the broad general wants of people are perhaps everywhere highly uniform—for example, a certain physical and social security and some fun. It is disagreement over the means toward these ends as represented by fantastic ideologies that result in conflict and chaos. I have pointed out that in proportion as a science is well developed, it can describe with accuracy *the consequences* of a variety of widely disparate programs of action. These consequences, if reliably predicted, are bound, of course, strongly to influence what people will want. But it remains a fact that

⁴ See, for example, "Industrial Conflict" (Cordon, 1939), Editor's Foreword and Chapter 1.

science, in the sense of a predictor of consequences, is only *one* of the numerous influences that determine an individual's wants and his consequent behavior.

As social science develops and secures recognition of its authority, however, there is every reason to believe that science will become a major influence in determining the wants of men as well as the means of satisfying them. By charting reliably the remote as well as the immediate consequences of the various possible courses of action, men's wants will be modified accordingly. In this way, science and scientists might be major influences in *determining* value judgments. The knowledge which constitutes science obviously already exerts this influence in some fields. When the social sciences attain maturity and respect, we shall no longer waste our energies in following the vain hopes of early and permanent salvation proffered by various ideologies which to-day seduce a large number of social scientists as well as the masses of men from more fruitful activities.

IV

So far I have dealt mainly with the obstacles which are alleged to prevent the social sciences from ever attaining the stature and functions already exercised to a large degree by other sciences. Since the future of the social sciences is obviously determined largely by the seriousness of these obstacles, I have deemed it proper to deal at some length with them. I have not tried to minimize these problems in the sense of overlooking the long and painstaking labor which their solution doubtlessly involves. I have merely suggested that these problems are soluble by the same general methods to which similar obstructions in other fields have yielded. At this point the question naturally arises: Has any progress been made in this direction? What are the achievements, if any, of

the social sciences thus far which warrant the optimistic view I have taken?

Any comprehensive review of the present status and achievements of the social sciences is obviously beyond the scope of the present discussion. Although I think it is unquestionably true that the social sciences have made, during the present century, more actual progress in the direction I think they must go than they made in all preceding history, it would be absurd to pretend that this progress is, as yet, reflected to any great extent in our management of social affairs. Scientific information of a more or less reliable character is more widely diffused than ever before, but the scientific mode of thought has obviously made very little headway. Practically no one approaches the major social problems of the day in a spirit of disinterested scientific study. The idea that these problems are to be solved, if at all, by the use of instruments of precision in hands that do not shake with fear, with anger or even with love,⁵ does not seem to have occurred even to many people who pass for social scientists. They have joined the journalist and the soap-box crusader in the hue and cry of the mob. Their supposedly scholarly works bristle with assessments of praise and blame, personalities and verbal exorcisms which have no place whatever in the scientific universe of discourse. Not only do these verbomaniacs pass in the public eye as great social scientists of the day, but they not infrequently presume to patronize honest scientists who stay with their proper tasks of building a science and the instruments by means of which any difficult problems are to be solved.

But behind this fog, this dust storm of books about the inside of this political movement, the private life and morals of its leaders and the treatises on democracy, substantial work is going on. Men are patiently accumulating data about human behavior in a form which in the

⁵ Cf. R. L. Duffus, *Harper's*, December, 1934.

fullness of time will permit a type of generalization which has never before been possible. Some are engaged in the undramatic but fundamental work, basic to all science, of classifying the multitudes of human groups and behavior patterns as a first step toward the formulation of generalizations regarding them. Still others are pioneering in the construction of actuarial tables from which may be predicted the probable degrees of harmony to be expected from intimate personal relationships of an almost universal type. Still others are experimenting with the invention and perfecting of instruments for the more accurate and precise observations and recording of social phenomena. It is easy to point to the flaws in these instruments as it was easy to point to flaws in the early microscopes and telescopes. But without these beginnings and the patient centuries of undramatic labor, sciences like bacteriology could not have appeared at all. Finally, there are those, and they are the most suspect of all, who are experimenting with and inventing new systems of symbolic representation of phenomena. New adaptations of mathematics by which otherwise hopeless complexities can be comprehended are quite fundamental but do not lend themselves to popular display. The work of Leibnitz, Faraday and Hertz was not the popular science of their day. Yet it is by virtue of their strange calculations with strange symbols that men to-day fly and broadcast their speech around the earth.

If I deal primarily with these more obscure and undramatic labors of social scientists, it is because I regard them as more important in the long run than the conspicuous contemporary achievements which are common knowledge. I do not overlook or underestimate these more obvious and demonstrable achievements. The transition in our time to more humane treatment of children, the poor and the unfortunate by more enlightened education, social work and penol-

ogy must, I think, in large measure be attributed to the expanding sciences of psychology and sociology. I know, of course, that whenever a war or a depression occurs journalists and preachers point to the impotence of economists and political scientists either to predict or prevent these disasters. The fact is that the course of events following the World War, down to and including the present, were predicted with great accuracy by large numbers of social scientists. That nothing was done about it is not the special responsibility of social scientists. It is the common responsibility of all members of a community, including scientists, and especially of those who specialize in mass education, mass leadership and practical programs.

But it is not my purpose to review the past and present achievements of the social sciences. I am concerned primarily with their probable future. Even if I should admit that social scientists are to-day merely chipping flints in the Stone Age of their science, I do not see that we have any choice but to follow the rough road that other sciences have traveled. The hope of arriving at a comparable success may seem remote, and the labors involved may seem staggering. But is the prospect really unreasonably remote? Suppose that some one four hundred years ago had delivered an address on the future of the physical sciences and suppose that he had envisioned only a small fraction of their present achievements. What would have been the reaction of even a sophisticated audience to predictions of men flying and speaking across oceans, seeing undreamed-of worlds, both through microscopes and telescopes and the almost incredible feats of modern engineering and surgery? Nothing I have suggested, I think, in the way of mature social science with comparable practical application seems as improbable as would the story of our prophetic physicist of four hundred or even one hundred years ago.

But what about the costs of such a pro-

gram? What price must we probably pay for a social science of a comprehensiveness and reliability comparable to some of the better developed physical sciences? The costs are undoubtedly considerable, and it remains to be seen to what extent humanity is willing to pay them. What are some of the principal items both as regards material and psychological costs?

The mention of costs suggests that I am about to digress into the subject of allocations of funds in university and other budgets. The advancement of science undoubtedly does involve costs of this type, but I shall not go into them because I am at present more concerned with other types of costs which have nothing to do with money or with budgets. Let me therefore dismiss the question of monetary costs with a brief estimate by Huxley in the article I have already quoted: "Before humanity can obtain on the collective level that degree of foresight, control and flexibility which on the biological level is at the disposal of human individuals, it must multiply at least ten-fold, perhaps fifty-fold, the proportion of individuals and organizations devoted to obtaining information, to planning, to correlation and the flexible control of execution." Even this may seem staggering to educators who are wondering how to maintain merely their present activities. Unquestionably this program will call for readjustments in our present national economy. But how does the entire expenditure for scientific research in the universities of the land compare with the price of a single battleship? The endowment for social science research in 16 leading universities totals only \$3,000,000, or an average annual income from endowment per institution of about \$7,500.^a Suppose the current census will cost 40 million dollars. A battleship costs about twice as much. The British, we are told, are spending for war purposes alone

^a The Rockefeller Foundation. "A Review for 1939," p. 42.

almost \$20,000,000 per day.⁷ Perhaps it will occur to some future generation to try a reallocation of such funds. If so, Huxley's proposal will be readily financed. But are we or some future generation likely to change so radically our notions of what is worth while spending money for? This brings us face to face with costs of science which come perhaps higher, and touch us more deeply, than any of its financial costs.

First of all, the advancement of the social sciences would probably deprive us in a large measure of the luxury of indignation in which we now indulge ourselves as regards social events. This country, for example, is enjoying at present a great emotional vapor-bath directed at certain European movements and leaders. We believe to-day apparently that the assassination of Hitler would quite solve the problems of Europe, just as we believed twenty years ago that hanging the Kaiser would achieve the same end. Such projects minister to deep-seated jungle-fed sentiments of justice, virtue and a general feeling of the fitness of things, as compared with what a scientific diagnosis of the situation indicates. In short, one of the principal costs of the advancement of the social sciences would be the abandonment of the personalistic and moralistic interpretation of social events, just as we had to abandon this type of explanation of physical phenomena when we went over to the scientific orientation.

Closely related and indeed inseparably connected with the necessary abandonment, in science, of personalistic and moralistic types of explanation is the necessity of abandoning or redefining a large vocabulary to which we are deeply and emotionally attached. Concepts like freedom, democracy, liberty, independence, free speech, self-determination and a multitude of others have never

⁷ A. Comstock, *Events*, May, 1940, p. 349. The estimate is from the report of the Chancellor of the Exchequer to the House of Commons, March 13, 1940.

been realistically analyzed by most people as to their actual content under changing conditions. Any such analyses, furthermore, are sure to seem like an attack upon these cherished symbols and the romantic state of affairs for which they stand. As every social scientist knows, these are subjects that had better be handled with care. We like to think that there are not as yet any storm troopers lurking in our colleges to drive out an Einstein. In the meantime our own storm troopers, no less the agents of a self-constituted political hierarchy masquerading under the guise of religious servants, achieve exactly the same result with respect to Bertrand Russell. Social sciences worthy of the name will have to examine realistically all the pious shibboleths which are not only frequently the last refuge of scoundrels and bigots, but also serve as shelters behind which we to-day seek to hide the facts we are reluctant to face. The question is, how much pain in the way of disillusionment about fairy tales, disturbed habits of thought and disrupted traditional ways of behaving will the patient be willing to put up with in order to be cured of his disease? He will probably have to become a lot sicker than he is before he will consent to take the medicine which alone can save him.

Finally, the advancement of the social sciences will cost the abandonment not only of *individual concepts* carried with us from prescientific times. It will require us also to abandon deeply cherished *ideologies*, resembling in form if not in content their theological predecessors. The notion of some final solution, preferably in our own generation, of the major social problems that agitate us is a mirage which even scientists have great difficulty in abandoning. Many of them still confuse the social sciences with various cults, religions and political dogmas. Only last year, for example, twelve hundred American scientists signed a manifesto declaring among other highly laudable sentiments that in their opinion

"in the present historical epoch, democracy alone can preserve intellectual freedom." If this was intended merely as a rhetorical expression of sympathy for the unfortunate and persecuted in other lands, I know of no decent person who would not gladly join them in such an expression. If, however, they want this statement to be taken literally as a scientific conclusion arrived at by the accredited methods of science, then these scientists have allowed their sympathies to overcome their judgment and have rendered a disservice to science by identifying it with a political dogma, namely, that state of affairs to which some of us are accustomed and which we happen to like.

I know of no scientific evidence whatever to indicate that democracy, or any other single system of social or political organization, is the *sole* system under which science can prosper. All that I can find any *scientific* warrant for is that under some conditions, democracy, defined in any constant way you please, is compatible with a certain degree and type of intellectual freedom. As for the main issue, every one with even a superficial knowledge of the history of science must know that some of the most notable triumphs of science occurred under régimes making no pretensions to democracy. Even to-day (1938-1939) three Nobel Prizes for science go to Italy and to Germany. To be sure, we also hear of attacks upon Einsteinian physics in Germany. We conveniently forget that the first truly popular democratic movement in Europe found "no use for scientists" and forthwith beheaded the father of modern chemistry. We conveniently forget that only a few years ago several states, under the leadership of American statesmen, passed laws against the teaching of evolution. These things *do occur* also in democracies. I would condemn them *wherever* they occur. I am opposed to making science the tail of *any* political kite whatsoever. Political systems have

changed, and they will change. Science has survived them all.

The mere fact that I, personally, happen to like the democratic way of life with all its absurdities, that I probably would find some current alternatives quite intolerable, and that I may even find it worth while to die in defense of democracy of the type to which I am accustomed, are matters of little or no importance as touching the scientific question at issue. My attachment to democracy may, in fact, be of *scientific* significance chiefly as indicating my unfitness to live in a changing world. To accept this simple notion is perhaps a cost of social science that few are prepared to pay.

Finally, what does the future promise for social scientists in the way of freedom to perform the tasks which I have outlined as their proper business? Here again, we need not expect to escape the troubles which other scientists have encountered throughout history. Chemists and physicists from time to time have suffered persecutions because of the conflict of their findings with more generally accepted views. They have continued to hew to the line, however, until to-day they enjoy a certain immunity and freedom of investigation which social scientists do not share. Why do physical scientists enjoy this relative security in the face of changing political régimes, and how may social scientists attain a corresponding immunity?

The answer is popularly assumed to lie, as I noted in the earlier part of my remarks, in the peculiar subject-matter with which social scientists deal. I doubt if this is the principal reason. I think a far more fundamental reason for the relative precariousness of the social sciences lies in their comparative incompetence.

Social scientists unfortunately have failed as yet to convince any considerable number of persons that they are engaged in a pursuit of knowledge of a kind which is demonstrably true, regard-

less of the private preferences, hopes and likes of the scientist himself. *All* sciences have gone through this stage. Physical scientists are, as a class, less likely to be disturbed than social scientists when a political upheaval comes along, because the work of the former is recognized as of equal consequence under any régime. Social science should strive for a corresponding status. Individual physicists may suffer persecution, but their successors carry on their work in much the same way. If social scientists possessed an equally demonstrably relevant body of knowledge and technique of finding answers to questions, that knowledge would be equally above the reach of political upheaval. The services of *real* social scientists would be as indispensable to Fascists as to Communists and Democrats just as are the services of physicists and physicians. The findings of physical scientists at times also have been ignored by political régimes, but when that *has* occurred, it has been the *régime* and not the *science* that yielded in the end.

What impresses me is the trivial effect of political interference upon the well-developed sciences. I recognize, of course, the frequently unfortunate effect of these movements upon individual careers and individual projects. But if we plot the course of scientific advance during the past two hundred years, the impressive fact is how little its main course has been deflected by all the petty movements of so-called "social action," including the major political revolutions. The demonstrable superiority of science as a method of achieving *whatever* men want has caused even its persecutors to return to it, after only very temporary and local crusades, chiefly against individual scientists.

I have emphasized that physical scientists are indispensable to any political régime. Social scientists had better work toward a corresponding status. Already some of them have achieved it to a degree. I venture to believe, for

example, that qualified social statisticians have not been and will not be disturbed greatly in their function by any political party. Their skill consists in the ability to draw relatively valid, unbiased and demonstrable conclusions from societal data. *That* technique is the same, regardless of social objectives. No régime can get along without it. It is the possession and exercise of such skills alone that justifies the claim of academic immunity. To claim it for those who insist on taking for granted that which needs to be demonstrated can only result in the repudiation for everybody of the whole principle of academic freedom. For the same reason, we had better not become so devoted to blatant crusades for academic freedom that we forget to bolster the only foundation upon which academic freedom can ever be maintained in the long run, namely, the demonstrated capacity of its possessors to make valid and impersonal analyses and predictions of social events.

My conclusion is that the best hope for the social sciences lies in following broadly in the paths of the other sciences. I have not tried to minimize the difficulties that beset these paths. I have merely argued that they are not insurmountable, and that in any case we really have no choice but to pursue this one hope. For we are already so heavily committed to the thoughtways and the material results of science in so large a part of our lives that we can not either go back or stand still. In short, the trends that have been strikingly evident in the social sciences in recent decades will, I believe, continue at an ever more rapid rate. Social scientists will talk less and say more. They will rely ever more heavily on a more economical type of discourse, namely, the statistical and the mathematical. Much of what now passes for social science will be properly relegated to other equally honorable departments, such as journalism, drama or general literature.

As such, this material will have its uses as propaganda, news, art and a legitimate outlet for the emotions of men. Indeed, nothing I have said regarding the possibilities of scientific study of human affairs should be interpreted as in any way contemplating an abandonment or a restriction upon the artistic, religious, literary or recreational arts which also minister to the cravings of men. I have on the contrary rather advocated that the social sciences had better not handicap themselves by aggrandizing to themselves roles which they can not fulfil.

Scientists had better confine themselves, I have argued, to three tasks: First and foremost, they should devote themselves to developing reliable knowledge of what alternatives of action exist under given conditions and the probable consequences of each. Secondly, the social scientist should as a legitimate part of his technology, as well as for its practical uses, be able to gauge reliably what the masses of men under given circumstances want. Finally, he should in the applied aspects of his science develop the administrative or engineering techniques of satisfying most efficiently and economically these wants, regardless of what they may be at any given time, regardless as to how they may change from time to time and regardless of the scientist's own preferences.

Thus the social sciences of the future will not pretend to dictate to men the ends of existence or the goals of striving. They will merely chart the possible alternatives, the consequences of each and the most efficient technique of arriving at *whatever* ends man shall from time to time consider it worth while to pursue. If the social sciences devote themselves effectively to this role, they have a future of unlimited possibilities and have nothing to fear from the changes that will doubtless occur in the future as they have occurred in the past.

CHRISTOPHER WREN, F.R.S.

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IN a general information test Wren's name would be associated immediately with architecture and perhaps with churches. Yet how many people to-day know when he lived or anything more of him than that he was the architect of St. Paul's Cathedral in London? Were they to be told that he has been responsibly named as "possibly the greatest Englishman after Shakespeare"¹ their astonishment would probably be great. This paper, therefore, presents some of the evidence for Wren's greatness as reflected in his achievements in science, and indicates the remarkable promise of the first third of his life before he became absorbed in his architectural labors, magnificent as these were.

Christopher Wren was born in England in 1632 and died early in 1723 in the ninety-first year of his life. This great span of life is in itself notable, for in the seventeenth century life expectancy was short. A man of sixty was old, and few indeed attained ninety years of age. Furthermore, Wren's old age did not lessen his mental powers nor slacken his physical strength unduly, for he remained active in his office as surveyor-general of the royal works until 1718 and was responsible for the repair of Westminster Abbey until his death five years later. Yet this long life was lived by a man whose youth had been too sickly for him to be sent to school except for a short time. His biographer (either his son or his grandson, for the "Parentalia" does not reveal which of the two wrote the various parts of the Wren papers published in 1750) comments on this:

¹ H. A. L. Fisher, as quoted by John F. Fulton, *Fale Jour. of Biol. and Med.*, p. 315. March, 1931.

As to his bodily constitution, it was naturally rather delicate than strong, especially in his youth, which seemed consumptive; and yet, by a judicious regularity and temperance, (having acquir'd good knowledge in physick) he continued healthy, with little intermission, even to this extreme old age. Further, 'tis observable, that he was happily endued with such an evenness of temper, a steady tranquillity of mind, and christian fortitude, that no injurious incidents, or inquietudes of human life, could ever ruffle or discompose; and was in practice a stoick.²

Another writer described him thus:

As to his person, he was low of stature, and thin; but by temperate and skilful management (for he was a proficient in anatomy and phisic) he enjoyed a good state of health, and his life was protracted to an unusual length. . . . He died as he lived, with great calmness and serenity, and little other sickness.³

Other notable facts about this great span of life are that Wren lived during six reigns, those of Charles I, Charles II, James II, William and Mary, Anne and George I, as well as through the Commonwealth, and that he held office under five of these rulers without interruption. Wren was a boy of ten when civil war broke out, and a student at Oxford at seventeen when Charles I was tried and beheaded. Nine years later he was kept out of his lecture room at Gresham College in London when soldiers under the Lord Protector seized the college for a barracks. His friends and relatives were among the political prisoners of those decades of war and revolution. He lived through the plague year of 1665, and from the fire of 1666 came his great opportunity: the rebuilding of the City of

² "Parentalia, or Memoirs of the Family of the Wrens . . . chiefly Sir Christopher Wren, . . . compiled by his son Christopher, now published by his grandson Stephen Wren, Esq.," p. 346. London, 1750.

³ John Ward, "Lives of the Professors of Gresham College," pp. 105, 106. London, 1740.

London. The Revolution of 1688 apparently did not affect his task of rebuilding other than to further it through the sympathetic, interested support and the excellent taste of Queen Mary. Nor for a time at least did the change to the Hanoverian dynasty cause him to lose royal favor. Not until 1718 did a jealous cabal, so it is stated, force him out of office and into retirement after fifty years of service under royal appointment.

Wren's first royal recognition of importance came soon after the restoration of 1660 from Charles II, that lover of clever men and beautiful women. Charles II placed Wren on a commission to solve the problem of how to preserve and restore the greatly dilapidated and neglected Cathedral of St. Paul's. Before any plans could be carried out the great fire swept through the City. At once Charles appointed Wren surveyor-general for the rebuilding of the City, though he did not accept Wren's masterly plan for the rebuilding of the burned area on a new and improved scheme. Robert Hooke was his assistant to supervise the building by private owners; but Wren himself was responsible for the building of St. Paul's Cathedral and fifty-one parish churches, two theaters and various other public structures. In addition, as surveyor-general of the royal works from 1669 to 1718, with the official responsibility for the upkeep and oversight of all the royal palaces and their subsidiary parts, he planned and built, among others, a large part of Hampton Court and Winchester palaces, Chelsea College and Royal Greenwich hospitals. Before his public work had become so overwhelming, in the 1660's and early 70's, Wren had already been the architect for the Sheldonian Theater in Oxford, the great library of Trinity College, Cambridge, and the Chapel of Emmanuel College, Cambridge. He had also made a survey of Salisbury Cathedral in 1669 for his

friend Seth Ward, Bishop of Salisbury. All this he did under each succeeding ruler through five reigns without regard to religious or political differences.

The story of these various buildings is in itself a notable one, reflecting not only Wren's genius as an architect but his tact and skill in dealing with kings and craftsmen, churchmen and poets, his integrity of character in insisting on solid foundations and honest workmanship, and a devotion to the public service that made him refuse all pay for his services in connection with the building of the Royal Greenwich Hospital for sick and pensioned sailors and their dependants, and that made him take a salary of only two hundred pounds a year for all the time St. Paul's was being rebuilt. A contemporary called Wren an English Vitruvius. Truly it can be said of him: he found London built of wood and clay; he left her built of brick and stone.⁴

But to return to Wren, the scientist and fellow of the Royal Society. When he was knighted by Charles II in 1674 Wren chose as the motto for his coat of arms "Numero, Pondere et Mensura," a reference to the verse in the Book of Wisdom (11:20): "But by measure and number and weight Thou didst order all things." Thus he registered his lifelong devotion to mathematics. Very early in his life this interest appeared and was fostered by the lessons of his brother-in-law, Dr. William Holder, himself a person of many accomplishments. His first recorded invention, an astronomical instrument, was made in 1645 when he was only thirteen years old and was soon followed by an instrument for planting grain, "A rustick thing" . . . he wrote "which shall plant corn equally without want and without waste."⁵ Before he was sixteen he had translated into Latin the section "on Geometrical Dialling" in Oughtred's "Clavis Mathematicae" with

⁴ "Parentalia," p. 324, 336.

⁵ *Ibid.*, pp. 182, 183.

such success that Oughtred in his preface to the "Clavis" wrote of Wren as:

a young man of marvelous gifts, who when not yet sixteen years of age, advanced astronomy, gnomonics, statics and mechanics by his distinguished discoveries, and from then on continues to advance these sciences. And truly he is the kind of man from whom I can shortly expect great things, and not in vain.⁶

Already the lad was the "darling of mathematicians,"⁷ well on his way to become, as Newton acknowledged later, one of the three foremost geometers of Newton's time.

After a short stay in Westminster School and some further time as an assistant to Dr. Charles Scarborough as demonstrator for his public lectures on anatomy, Wren went to Oxford where he was recorded a gentleman commoner at Wadham College in 1649.⁸ He probably went there earlier, however, for he was granted his B.A. in 1650, his M.A. in 1653. He was at once elected fellow of All Souls. He continued to live at Wadham College until summoned to London by appointment to the professorship of astronomy at Gresham College in 1657. Wadham College was then enjoying the most illustrious period of its history under the wardenship of Dr. John Wilkins, himself a lover of men and of the "new philosophy," experimental learning. Dr. Wilkins' moderate and tolerant rule of the college during the years of the Commonwealth made it attractive to the sons of cavaliers and roundheads alike, and drew about him in or near the college such science-lovers beside Wren as Robert Boyle, Laurence Rooke, Dr. John Wallis, William Petty and Seth Ward. These men with others of like interests formed the philosophical or scientific club that met first at Dr. William Petty's lodgings and then at the War-

den's rooms with greater or less regularity until Wilkins resigned in 1659 to become Master of Trinity College, Cambridge. With these men at Oxford, most of whom were later to be charter members of the Royal Society, Wren found most congenial and stimulating companionship, and they a genius whom Evelyn called "that miracle of a youth."⁹ Evelyn wrote in his diary 13 July, 1654, that he had dined at the college with Warden Wilkins and that the Warden had "above in his lodgings and gallery, variety of shadows, dials, perspectives and many other artificial, mathematical and magical curiosities, a way-wiser, a thermometer, a monstrous magnet, conic and other sections, a balance on a demicircle; most of them his own and that prodigious young scholar, Mr. Christopher Wren; who presented me with a piece of white marble which he had stained with a very lively red, very deep, as beautiful as if it had been natural."

Wren's fertile brain was too active during these ten or twelve years to be limited to any one field. In the "Parentalia" is a list of fifty-three "New Theories, Inventions, Experiments and Mechanich Improvements, exhibited by Mr. Wren, at the first Assemblies at Wadham-College in Oxford, for Advancement of Natural and Experimental Knowledge, called then the New Philosophy; some of which, on the return of the publick tranquillity, were improved and perfected, and with other useful Discoveries, communicated to the Royal Society."¹⁰ They range from a "picture of the Pleiades," and an "artificial eye with the humours truly and dioptrically made" to "several new ways of graving and etching," "divers new musical instruments," and "the best ways for reckoning time, way, longitude and observing at sea." The practical applications of his experimental knowledge were a constant con-

⁶ *Ibid.*, p. 184.

⁷ *Loc. cit.*

⁸ Robert B. Gardiner, "The Registers of Wadham College, Oxford, from 1613 to 1719," p. 178. London, 1889.

⁹ "Diary," July 11, 1654.

¹⁰ "Parentalia," pp. 198-199.

cern to him, this problem of the determination of longitude, for instance, recurred to him again and again throughout his life, and even occupied his old age after his retirement from public office. It was during this Oxford period too that he solved the mathematical problem sent by Pascal by way of challenge to the mathematicians of England. In return Wren posed another problem to which the French savants never replied.

The virtuosi at Oxford must have rejoiced at the recognition given Wren in 1657 when he was appointed professor of astronomy at Gresham College in London though he was not yet twenty-five years old. The opening paragraphs of his inaugural speech were as follows:

Looking with respectful awe on this great and eminent auditory, while here, I spy some of the politer genii of our age; here, some of our patricians; there many choicely learned in the mathematical sciences, and everywhere, those that are more judges than auditors; I can not, but with juvenile blushes, betray that which I must apologize for. And indeed I must seriously fear, lest I should appear immaturely covetous of reputation, in daring to ascend the chair of astronomy, and to usurp that big word of demonstration, *Dico*; with which (while the humble orator insinuates only) the imperious mathematician commands assent; when it would better have suited the bashfulness of my years, to have worn out more *lustra* in a Pythagorean silence.

I must confess I had never design'd anything further, than to exercise my radius in private dust, unless those had inveigh'd against my sloth and remissness, with continual but friendly exhortations, whom I may account the great ornaments of learning and our nation, whom to obey is with me sacred, and who, with the suffrages of the worthy senators of this honorable City, had thrust me into the publick sand. That according to my slender abilities, I might explain what hath been deliver'd to us by ancients, concerning the motions and appearances of the celestial bodies, and likewise what hath been found out of new by the modern; for we have no barren age; and now in this place, I could point to inventors; inventors, a title so venerable of old, that it was merit enough to confer on men patents of divinity, and perpetual adoration.¹¹

¹¹ *Ibid.*, p. 200.

Gresham College of the seventeenth century is to-day little known as compared with Oxford and Cambridge; but to the citizens of London in the century of the Stuart kings, it was an important center of learning. Founded by the will of Sir Thomas Gresham, Queen Elizabeth's financial adviser, it began its career in 1597 in what had been his residence. There the seven professors of geometry, astronomy, music, rhetoric, medicine, theology and jurisprudence lectured and had their living quarters, and there the virtuosi of the day, many of them newly returned to London, came on Wednesdays to hear Mr. Wren lecture on astronomy and on Thursdays to attend the geometry lecture of Mr. Rooke. One of Wren's lectures was on the telescope, to the improvement of which he had greatly contributed. Another was on the planet Saturn, then a topic of especial interest. As part of his work he invented a method for the construction and demonstration of solar eclipses. After the lectures his friends would gather in the lecturer's apartment to discuss with him and with the other virtuosi not only the topic of the afternoon but other subjects of common interest. Finally out of these discussions, the roots of which ran back to the weekly meetings of the Oxford science-lovers, and of the "invisible college" group in London of the forties and fifties, developed the idea of a formally organized society to be under royal patronage for the furtherance of natural knowledge. On November 30, 1660, at the meeting after Mr. Wren's lecture this decision was crystallized, the society founded, and in 1662 it was chartered as the Royal Society.

In this first charter of 1662 are listed the officers and the members of its first council while those who formed the membership that year were the original or charter fellows. On the first council was named Mr. Christopher Wren, "doctor

in medicine."¹² This reference to Wren as "doctor in medicine" is interesting; for I have found no other reference or evidence showing that Wren ever received the M.D. Oxford gave him the D.C.L. in 1661 and Cambridge later the same honor, but not the medical degree. On the other hand, by 1661 Wren had already done so much work in anatomy and dissection not only as an assistant to Dr. Scarborough before he went to Oxford, but with Dr. Willis and the other physicians at Oxford that perhaps the fame of his anatomical drawings made whoever wrote the list of names identify him as "doctor in medicine" along with the medical men also on the council. Whatever the reason for this title, Wren's name was only in the first council list and not in the second of 1663, probably because having resigned his Gresham professorship in 1661 he had returned to Oxford after his appointment there as Savilian professor of astronomy.

Whether in London or in Oxford, he was a moving spirit of the Royal Society in its early days, often reporting before it on his own experiments and suggesting ways, particularly in the recording of weather conditions, how the fellows could all further most important but hitherto neglected parts of natural knowledge. When the Society in 1661 [*sic*] was preparing to receive King Charles II as a guest at one of its weekly meetings, Wren proposed from Oxford various demonstrations for his entertainment in answer to a letter from the president, Lord Brouncker, asking for suggestions. Wren's reply¹³ is worth quoting in part, for in discussing what he considered proper for such a solemn occasion he reveals his own interests, and also his good practical sense; for, he commented, what is shown should at best "open new light into principles of philosophy," and

¹² "The Record of the Royal Society of London," 4th edition, p. 229. London, 1940.

¹³ "Parentalia," pp. 224-227.

in any case should be "something luciferous in philosophy and yet whose use and advantage is obvious, and without a lecture; and besides may surprize with some unexpected effect, and be commendable for the ingenuity of the contrivance." He continued:

For myself I have not anything by me suitable to the idea I have of what ought to be perform'd before such an assembly. Geometrical problems, and new lines, new bodies, new methods, how useful soever, will be but tasteless in a transient show. New theories, or observations, or astronomical instruments, either for observation or facilitation of the calculus, are valuable to such artists only who have particularly experimented the defects that these things pretend to supply. Sciographical knacks, of which yet a hundred varieties may be given, are so easy in the invention, that now they are cheap. Scenographical, catoptrical and dioptrical tricks, require excellent painting, as well as geometrical truth in the profile, or else they deceive not. Designs of engines for ease of labour, or promoting anything in agriculture, or the trades, I have occasionally thought upon divers, but they are not intelligible without letters and references, and often, not without something of demonstration. Designs in architecture, etc., the few chymical experiments I have been acquainted with, will, I fear, be too tedious for an entertainment. Experiments in anatomy, though of the most value for their use, are sordid and noisom to any but those whose desire of knowledge, makes them digest it. Experiments for the establishment of natural philosophy are seldom pompous; 'tis upon billiards, and tennis balls; upon the purling of sticks and tops; upon a viol of water, or a wedge of glass, that the great Des Cartes hath built the most refined and accurate theories that human wit ever reach'd to; and certainly nature in the best of her works is apparent enough in obvious things, were they but curiously observ'd; and the key that opens treasures, is often plain and rusty, but unless it be gilt, 'twill make no show at court. If I have been conversant in philosophical things (as I know how idle I have been) it hath been principally in these ways. . . .

He finally suggests from among his own devices, "the weather-wheel (the only true way to measure expansions of the air)," an artificial eye—"at least as big as a tennis ball," and lastly "a needle that would play in a coach" (a kind of compass) and joined with a way-wiser

(an odometer) would be both useful and diverting to a traveler and also might be an acceptable present for the king.

From this list the reader can see that Wren's love of experimental learning was not limited to the mathematical and physical sciences—astronomy, optics and mechanics—but extended to the chemical and anatomical ones as well. It is also apparent that practical applications were of primary significance to him. His inventive ingenuity was constantly at work whether to devise an instrument of two pens for writing double, to construct a weather gauge to measure rainfall or an instrument to record temperature changes throughout the twenty-four hours, or to regulate the size of aperture for telescopes and microscopes. His mechanical genius was so marked that his fellow worker Robert Hooke, an inventive genius himself, wrote of Wren in 1665: "of him I must affirm that since the time of Archimedes, there scarce ever met in one man in so great a perfection such a mechanical hand and so philosophical a mind."¹⁴

Like his love for mathematics, Wren's skill of hand and inventive ability were apparent very early in his life. As a lad in his teens he had not only acted as a demonstrator for Dr. Scarborough in his public lectures at the Surgeon's Hall but he had made anatomical models for him out of pasteboard. This anatomical work, especially on the muscles of the human body, was believed the first in anatomy to be based on geometrical and mechanical principles.¹⁵ Unfortunately these models were destroyed in the Great Fire some twenty years later. At Oxford in his student days Wren continued his anatomical studies, working with Dr. Willis on his classic dissections of the brain and drawing the plates of these dissections for Willis's book "*Cerebri Anatome*" (1654). In fact Dr. John Fulton pointed

out some years ago that "Willis mentions that Wren made the remarkable figure of the base of the brain which shows so clearly the arterial circle." Dr. Fulton continued: "I have always suspected that it was Wren and not Willis who made the discovery of the circle, for the vessels that he drew had evidently been injected and the plate itself is very much clearer than Willis's description in the text."¹⁶

The structure of fishes, the anatomy of nerves, the character of various organs in animals, and the humors of the eye with attendant problems of wisdom—all these attracted Wren's attention and provided problems he sought to solve. To the twenty-four year old Wren are credited the first suggestion and successful demonstration of the infusion of a liquid directly into an animal's vein—a procedure startling in its novelty in 1657, and one that had as its immediate successor in 1659 the transfusion of blood from one animal to another and later from a sheep to a man.¹⁷ Experiments in transfusion, indeed, became quite the fashion in experimental circles during the early 1660's as Wren's ideas and methods were developed by other virtuosi. For some of this scientific work Wren used the crude microscopes of the period; immediately he found ways to improve both the lenses and the use of them as well as to record what they revealed. His drawings of a louse, a flea and a nit as seen under a microscope found their way into the cabinet of treasures owned by King Charles and led to a request from the king that he do more of these "divine works" (to use Sprat's name for them).¹⁸ By this time, however, Wren was deep in other matters and he asked the king for release from this task. He encouraged Robert Hooke to go on with these studies instead, with the result that in 1665

¹⁴ Fulton, *op. cit.*, pp. 313-314.

¹⁷ "*Parentalia*," pp. 227-235.

¹⁸ *Ibid.*, p. 258.

¹⁴ "*Micrographia*," Preface. London, 1665.

¹⁵ "*Parentalia*," p. 187.

Hooke published his "Micrographia," the classic book on microscopic work.

This attitude toward his work was apparently characteristic of Wren. He had far more ideas and schemes than he could carry out himself, he cared not for fame nor for credit, and only occasionally did he bother to record priority of discovery when he found others disregarding his accomplishments or claiming his ideas as their own. As his biographer wrote:

His communicative temper in lending out papers, never recovered; his peculiar modesty and disregard of public applause, and of those methods by which men of the world usually proclaim and support the merits of their own performances, prevented the appearance in public, under his own name, of many useful tracts, and occasioned his not carrying on divers discoveries to perfection.¹⁹

Some of Wren's friends in their loyal admiration were jealous of his fame for him and did their best to have justice done him. When Thomas Sprat wrote his "History of the Royal Society" in the years before 1667, he described Wren's activities in some detail as a most notable illustration of the work being done by the fellows. Sprat did this because he found the Society's records were incomplete, "many excellent things, whose first invention ought to be ascribed to him," having been "casually omitted."²⁰ On this point the biographer remarked:

Sir Christopher has been heard sometimes to reflect sharply on the disingenuity of Mr. Oldenburg [one of the two secretaries of the Royal Society] who had neglected not only to enter divers inventions and experiments of his in the Registers of the Society, but conveyed the same into foreign parts, France and Germany; where they were after published under other names, as their own.²¹

Wren was not yet thirty when he returned to Oxford, in 1661, to be Savilian

¹⁹ *Ibid.*, p. 247.

²⁰ Thomas Sprat, "History of the Royal Society," pp. 311-317. Second edition. London, 1702.

²¹ "Parentalia," p. 247.

professor of astronomy, and all his architectural achievements were still ahead of him. Yet the next year Isaac Barrow, whom Charles II called the best scholar in England,²² in a lecture at Gresham College spoke of Wren as follows:

There is definite agreement that no one ever displayed more precocious hopes, so no one has produced riper fruits; formerly a prodigy of a boy, now a miracle of a man, or rather a supernatural (daemonic) human being; and moreover so that I may not seem to be a liar, it should be sufficient for me to have named the most gifted and superlatively good Christopher Wren.²³

It is not to be wondered at that Wren was welcome company among the best minds of the time. He it was who suggested to Robert Boyle to use mercury in his barometer tube, who had John Evelyn as godfather for his first born son, and who was consulted by Seth Ward, when Bishop of Salisbury, about the repair of that beautiful cathedral. Sprat's letters to his "Kit Wren" are full of friendship and good humored admiration. And Charles II called Wren up to London in 1663 to consult about the repairs that were most necessary for that sadly dilapidated church, St. Paul's. Wren even then advocated a cupola for that building in place of the much loved but very unsafe steeple; but he did so unavailingly for tradition and public opinion were against him, until the destruction wrought by the Fire of 1666 made necessary the complete demolition of the old structure. The king put Wren in charge of the rebuilding of the City after the fire; and when the old surveyor-general of the royal works finally died in 1669, he at once commissioned Wren as his successor. With the development of his responsibilities as an architect, Wren had to withdraw from his more specialized scientific pursuits. He resigned his Oxford professorship in 1673, when he

²² Walter Pope, "Life of . . . Seth, Lord Bishop of Salisbury," p. 164. London, 1697.

²³ Ward, *op. cit.*, p. 97.

was forty, but he found time to serve as president of the Royal Society in 1680–1682. Always, he had the furtherance of science at heart, even seeking to plan the Monument, and also the great staircase in St. Paul's to serve as tubes "to discover the parallax of the earth" as an aid to astronomers.

Mathematician, astronomer and physicist, meteorologist, anatomist and chemist, inventor and architect, skilled draftsman and excellent Latinist, honest craftsman and public servant—Wren was in the opinion of Pepys, "a worthy man."²⁴ Before Wren was thirty-four years old, the Fire of 1666 practically put a close to his scientific career, even though he was later to be president of the Royal Society. After 1666 Wren became preeminently the architect, prob-

²⁴ "Diary," March 21, 1668–69.

ably the greater in his new field because of his remarkable skill in mathematics, especially in geometry, and his exceptional powers of draftsmanship as was manifest in connection with his anatomical and microscopic studies. Essentially modern in his application of theory to practical use, he would surely with his "way-wiser" and his double-writing instrument, for example, have also felt at home among the inventors of gadgets to-day. But these were the trifles, dreamed of, tried and passed on for other men to develop or not as they would.

If you seek his true monument, go to St. Paul's and look around you. As architect, as scientist and as a versatile genius, Wren's work gives considerable foundation for Warden Herbert A. L. Fisher's comment on him, "possibly the greatest Englishman after Shakespeare."

YOUTH AND EDUCATION

CERTAIN broad over-all changes occurred in the lives and expectations of young people as a class during the decade 1930–1940. Census data tell us that the proportion of boys and girls aged fifteen to nineteen, inclusive, who were in school and not working increased by 25 per cent. This took place in a nation which already was schooling more of its older youth than any other country in the world. The proportion of young people who were employed decreased during that same period by more than 30 per cent. The number of boys not in school and not working increased in the first half of the decade and then decreased toward its close. . . .

What happened in the schools and colleges during the 1930's? How did they respond to the social and economic changes of the period? They responded slowly, for educational institutions are conservative. Boys and girls in the average school or college in 1940 took more or less the same courses that their predecessors took in 1930 and in 1920. But in a number of schools and colleges, a ferment has been at work, and trends are now apparent that may make great differences in the high schools and colleges of 1950 or 1960. In at least a hundred secondary schools and about fifty colleges that education of 1940 is notably different from that of 1930.

Central High School of Tulsa, Oklahoma, is one case where considerable changes have taken place. . . .

In 1930, as in 1920, the high-school courses of most of the students in Tulsa were dictated by college entrance requirements, although not more than 15 or 20 per cent. were to sit in a college classroom. In 1932 the Tulsa Central High School began to take part in the Eight Year Study of the Progressive Education Association involving thirty secondary schools, and thus was freed from meeting the ordinary college entrance requirements for certain specified courses. . . .

Young people in Tulsa assumed more responsibility for planning their own education. To manage their classes, they formed committees to work with the teachers, and had individual talks with them leading to better mutual understanding as time went on. Part of the day each student worked on projects which he chose as his way of making a contribution to some common problem. The study of such community problems as health and housing was begun and, with their English teachers, they related their work in reading and writing to their work in civics and science.—*Annual Report of the General Education Board, 1940.*

THOUGHTS ON SUBSPECIES

By W. L. McATEE

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RECOGNITION of avian subspecies has been the subject of comment more often aspersive and rancorous than judicial and broad-minded. The rank and file of American ornithologists and often, also, the leaders have dealt with subspecies as hard facts, to the neglect of underlying principles. Not a systematic ornithologist, the writer worked for twenty years on the classification of insects and described hundreds of species (as well as many subspecies and varieties) of those animals. This should be sufficient background for a discussion of subspecies, and experience with a group other than birds should give a detached point of view not easily attained, perhaps, by those who have been in the thick of the ornithological subspecies battle.

The writer has also been more or less deeply absorbed in bird study since boyhood and he has never worried about a subspecies yet. Why worry? There is no compulsion to deal with subspecies upon those who do not wish to do so. Oologists, especially, have denounced hair-splitting and name-changing, but why did not those who felt that way simply ignore subspecies? By taking them too seriously, they permitted others to rule their specialty. They need not have striven for a "set" of every additional form named; they could have made their own catalogue of what they deemed "good species" and have used it as standard in their guild.

Observers who study ornithology for pleasure (the vast majority) need not take account of subspecies—which are rarely subjects for field recognition anyway. These students legitimately may be, and mostly are, interested in birds primarily, in species, secondarily, and in

subspecies, not at all. If necessity arises, they can read in some book what is known about the subspecies concerned.

The need for bird names on the part of ornithologists, who care not for subspecies, can be met entirely by a code of vernacular names of species (not provided, it must be admitted, by the current A.O.U. Check-List). These bird students, if they will, can go their way in peace wholly untroubled by the doings of the subspecies makers and check-list compilers.

What of those who do care for subspecies and want to use subspecific names? Considering the advantage they should have in commenting upon subspecies, some of their remarks have been about as pointless as those of ornithologists far less informed. For example, we read that "subspecies may be sharply defined or they may also be united by intermediates." This pronouncement ignores the very definition of subspecies; they are forms connected by intermediates; the "sharply defined" forms are species. Some have railed at subspecies because every collected specimen can not be promptly and positively identified. If the going were as easy as that, it would indicate that species, not subspecies, were being dealt with. Subspecies are not another kind of thing like species, but less well marked—no, they are fractions of species—colonies, the individuals of which are in no way trenchantly marked off from those of other colonies.

Often we read of "good" or of "poor" subspecies, terms that are not properly applied to segregates correlated with geography, physiography and ecology, and just as valid as the distinctions in their habitats whatever the degree of

expression. In a word, many, perhaps all, species tend to be modified in response to environment. A species between the extremes of its distribution may range over a number of types of country in each of which it may develop precinctive characteristics. These diversities are correlated with environment. Whether caused by environment, and how, are separate questions. As changes in environment are usually gradual, so those in color, form and measurements of the bird inhabitants, as a rule, are intergrading in character. Species embrace individuals that are most closely like their nearest neighbors, and those neighbors with the next beyond and so on. Such intergradation is known to extend clear across the continent and connect forms, which if the intermediates were eliminated would rank as distinct. The greatest American ornithologist has compared such a complex of subspecies to the imperceptibly merging colors of the spectrum.

Sometimes, however, birds having the subspecific characters of one region are found breeding in another area. These may be strays or mutants or they may represent other aberrations of distribution or heredity. Such mixtures of genetic strains may in certain instances obscure the subspecies concept, but they do not affect its general validity.

Some birds are more plastic, reflect environmental change more than others, but theoretically any species of wide range, if it have the attachment to territory now held to be characteristic of practically all birds, theoretically at least, it may be repeated, such a species must be affected in some degree by any differentiation areas included in its general range.

The reality of differentiation areas may be brought home by consideration of the results of subspecific classification as officially accepted by the American Ornithologists' Union (1931 Check-

list). Florida, for example, has more than thirty subspecies nearly or entirely restricted within the limits of the state, so far as distribution in the United States is concerned. Individuals of a number of these races average smaller than those of the next adjacent subspecific segregate. For another southern illustration, consider the tip of Lower California or the Cape District, from which nearly fifty currently recognized subspecies have been described. Here is a district limited in size and in ecological variety but one which is an avian differentiation area with emphasis. The northern part of the peninsula also has yielded about an equal number of recognized subspecies. Probably all have read about the Brownsville birds and the furor they caused. They were sixteen in number; now about fifty subspecies are known to occur in the United States only in southern Texas. An equal array range from the next adjacent district of the arid Southwest through similar country in Mexico and a goodly number are found only in the mountains farther west and in comparable parts of the Mexican Tableland. The desert forms are notable for their pallor, while those of the humid northwest coast are characterized by somber coloration. There are about forty subspecies in the latter group, mostly ranging from southern Alaska or British Columbia to Oregon or northern California. The northeast coast also is a differentiation area, twelve subspecies now being recognized from the Newfoundland, Nova Scotia, New Brunswick region.

It is easiest to deal with peripheral parts of our territory, but it should not be overlooked that the mid-continent also has peculiarities that are reflected in differences in the bird inhabitants. For instance, the zone of transition from the humid east to the arid west south of the transcontinental coniferous forest is one of vast significance in the distribution

and modification of organisms in general. Among birds, we recognize an eastern and a western willet, solitary sandpiper, dowitcher, mourning dove, yellow-billed cuckoo, house wren, mockingbird, robin, golden-crowned kinglet, ruby-crowned kinglet, warbling vireo, yellow-breasted chat, meadowlark, evening grosbeak and eastern and western subspecies of the Savannah, Henslow's, vesper, lark, tree, chipping and field sparrows.

Geographic, physiographic, ecologic, or whatever the influence forming subspecies may be, obviously it is of great importance in connection with the differentiation of birds and when coupled with isolation, its effects often are intensified. The island forms well illustrate this point: more than twenty accepted subspecies have been described from the California and Queen Charlotte Islands, four from the latter group alone. Seven subspecies of rock ptarmigans and six of winter wrens are recognized from islands of the Aleutian chain. The clapper rails, marsh wrens and seaside sparrows from almost every sizable tract of salt marsh seem to be distinguishable and numerous subspecies have been described.

No more need be said to prove the existence and the effects of differentiation areas. They would no doubt appear more definite had progress in bird classification been less haphazard. Forms were described as they came to hand and ranges worked out later. Often the type specimen was a variant that would not have been selected had more material and fuller knowledge of ranges been available. Then another describer may have defined a form distinguishable from those previously described, but still for lack of material and knowledge, not centrally located in its area of differentiation.

How much better could all this have been done if the concept of differentia-

tion areas could have been developed first, and a grid of those areas prepared that would show where recognizable variants of any wide-ranging and plastic species might be expected. It would seem self-evident for every such species, considering its continuously intergrading variation, correlated with environment, that there will be in each differentiation area an association of individuals more like each other than like those of other areas, that may be recognized as subspecies if desired. If our beliefs as to territorialism and environmental response are correct, local populations will in some degree be modified in the differentiation areas whether the effects are readily discernible or not. In other words, named or unnamed, subspecies of some degree are present in each differentiation area. This is a phenomenon of nature, not a fancy of man. Practice as to description of these forms is in the hands of the taxonomists, and policy as to official acceptance of them in those of the Committee on Classification and Nomenclature. As to use of the names, no one need use them; that is a matter of choice.

The facts are plain, however, and recognition of them should put an end to carping of big-wigs about millimeter races, and complaining by little-wigs as to the prospect of every county having a separate subspecies of each bird. Furthermore, the supposedly devastating criticism that a bird without locality label can not be identified to subspecies is no criticism at all, for it is precisely localization and local environmental moulding that permit subspecies to be defined. A safe rule would be not to attempt subspecific identification except of known breeding birds very precisely labeled as to locality.

On this point Taverner writes, "It is very important that subspecies be made only from breeding birds. The naming of migrants or winter-visitors and then

guessing as to their probable origin is responsible for much misleading work. . . . If no one ever made a subspecific identification without observed subspecific evidence ornithology would be a long way ahead today" (letter of April 21, 1938).

If continuous intergradation through the range of continental species is the universal phenomenon it appears to be, then all specimens can not be sorted to subspecies except on a geographical basis. In a great deal of subspecific definition that has been done, the lines of separation between the forms, which

it has seemed advisable (to the author, compiler or committee) to name, have been arbitrary. The accepted limits of life zones or of other ecologically significant areas, consciously or unconsciously, however, have been the guide in numerous instances. If a subspecific grid such as suggested here could be worked out as representing generally effective differentiation areas, the problem of what to recognize would be much simplified. It would be of great value also in enlightening critics as to the inevitability of subspecies and as to the realities underlying subspecific nomenclature.

SCIENCE AND MORALS

By JOSEPH B. GITTLER

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VERY few people will disclaim the fact that there is an enormous amount of confusion in the ethical thinking of the present day. Much disagreement eddies about the problems of the criteria of good and bad. A group of college seniors were questioned about the rightness of lying and killing. Without hesitation their reply was that both were wrong. When asked further whether lying was right in the case of a physician telling a heart patient that he had two months to live, thus subtly killing him much sooner, the answer became more hesitant. It was generally considered that to lie is bad, but to kill is much worse. When questioned again as to the badness of lying, the students became more confused and were in a quandary.

I cite this as one illustration of the confusion that exists in our everyday ethical thinking—it is not difficult to see why this chaos prevails. The confusion is due largely to the arbitrary, conventional and traditional manner that we have adopted in determining our criteria of good. This arbitrary

selection of standards has taken many forms. The standards of good are often set up and accepted by the individual or group, without any intellectual questioning of the standard; or without ever having had the occasion to witness or to experience that good. We can illustrate the former by the fact that a great many people are proud of being "modern." The latter may be illustrated by a group of twenty-five students, twenty of whom considered that it would be worth while to reintroduce the practice of the minnesingers; of these twenty, only two were familiar with the age of the minnesingers. The others knew only that they were those who used to compose popular medieval lyrics. Five of the total did not commit themselves.

Confusion arises too in our ethical thinking when people hesitate to question existing institutions. All the twenty-five students considered it worth while to go to college, because 'every one goes to college these days.'

M. R. Cohen's illustration by a parable in his "Reason and Nature" shows this

dilemma clearly: "Suppose that some magician came to us and offered us a magic carriage having great conveniences, but demanded of us in return the sacrifice of thirty thousand lives every year. Most of us would be morally horrified by such an offer. Yet when the automobile is actually with us, we can invent many ingenious arguments against the proposal to abolish it."

Although the above difficulties are characteristic of the so-called "common-sense" group, the confusion becomes even greater when moral philosophers furnish us with subtle substitutions for arbitrary standards of good. I refer to the metaphysical-ethical theories of teleology, formalism, hedonism, and so on.

For the purpose of this paper I wish to classify ethical thinking into two general schools: the absolutist and the relativist.

The confusion surrounding the absolutist way of thinking may again be illustrated by the situation about lying cited previously. Let us consider the commandment "Thou shalt not kill." If we were to apply this commandment absolutely the absolutist would of necessity have to be a vegetarian, for to kill an animal is as wrong as to kill a man. Further, an absolutist tending to uphold heroism can hardly, also, account for laurels won for brave deeds, which must of necessity consist of prizes for bigger and better killing.

On the other hand, the relativist who fails or hesitates to accept the existence, validity, reality, of moral standards can easily be led to a moral morass which might be even more chaotic than his absolutist brother.

It is therefore the contention of this paper that in order to overcome this confused state of affairs, we must employ a scientific approach to our ethics and morals. I am fully aware of the objections raised to the employment of science in ethics—objections ranging from the

lack of desire to employ it to the claim that ethical man is not a scientific creature.

It is not so much the intention of this paper to answer the persistent objections raised against a science of ethics. Rather it is my intention to point out ways in which we might make some progress in our ethical thinking. To my mind the solution lies in the adoption by ethics of that phase of the scientific method which is applicable here, *viz.*, the universal-rational and the objective.

I do not propose to go into an elucidation of the scientific method as such; neither do I claim that the general accepted procedure of science is totally applicable to the moral realm—but I see in some phases of science a possible approach to a better understanding of our morals and of our ethical evaluations.

Our mode of procedure might be as follows. Instead of hapahazardly and arbitrarily considering anything as good, rather let us consider what are the inevitable and necessary facts of human nature, such as desire for food, life, sex, health, and so on. In short there are certain things that must be, before other things should be. Anything that tends to destroy life or civilization, such as war, poor hygienic conditions, disease, etc., have to be considered as bad; things that tend to satisfy man's fundamental wants, as good. There are, however, some modifications. Thus we may start with the fundamental assumption that personal possessions are essential and necessary. We may then employ this law in society. It will then lead us to a qualification of this principle, *viz.*, if in society all people seek personal possessions, these possessions must become limited in so far as the interests of the many are concerned. Thus we are also overcoming the possibility that the overemphasis of one need, as sex, may become detrimental to another need as life itself.

It is this phase of science that is both helpful and remedial to our confused state of morals. Before we can proceed to declare what good should prevail, we must discover what human activities must prevail. This is synonymous with the discovery of natural laws. It will not be difficult to ascertain these inevitable goods. The manner in which this can be done, while sometimes considered dialectical is, however, not accurately described by that term. I refrain from culling a name for this type of procedure, but wish to point out just what it is. (I might here mention that this very inadequacy and inexactitude of language has led to the creation of semantics and symbolic logic.) Let me use an illustration to clarify my point. The N.R.A., the institution of Ford, are not inevitable to man—remove these institutions and man can still exist in various other ways—however, take away food or means of getting food and man is eliminated altogether. The latter illustrates inevitable values. This has the earmarks of the biological approach in ethics, but that is merely because of the example used. Beauty may be fundamentally essential to man as well. Beauty may prove destructive to man—it must be tested by inevitable values.

Even though this procedure does not eliminate the probable character of ethical judgments, we must be ready to accept the method of caution rather than

one of whim and sentiment. To the complaint that the enumeration of the fundamental facts may become more complex and more involved and the consequent criteria of good more pluralistic, our answer is that the law of gravitation does not apply to colloidal chemistry. If we make it apply—and perhaps by some schematic instrument of logic we can make it apply—it would not be significant as a law of natural phenomenon at all. Moral phenomena are more numerous than types of natural phenomena and there consequently must be expected a larger number of hypotheses or generalizations.

Ethics is interested in creating a good man and a good society. The advantage of the moral over the natural is that the natural phenomena are and must be as we discover them; moral phenomena have to do with intelligent activity which should be used as an instrument of accepting if good, and rejecting if bad.

A great many thinkers consider this method autocratic. We surely ought not to be sidetracked by such irrelevancy; for in so doing they are merely making an appeal to our emotions and raising objections which cloud the issue. If a thing is good, having been arrived at in the method described above, then we ought conscientiously to pursue that thing. We ought not to quibble about autocracy—we ought to be delighted to follow what is right.

THE MYTH OF POISON GAS

By MORRIS GORAN

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SEVENTY-EIGHT thousand soldiers died from the effects of poison gas in the World War; one million more were counted as casualties from this weapon. On the other hand, approximately eight and one half million men were killed, and twenty-one million men were wounded through other means. Thus the poison gas toll is less than one per cent. of the total, with the great majority of casualties occurring during the early years of the war, when gas masks had not been developed.

These facts have not impeded a constant attack against poison gas; people shocked by modern warfare point to it as a symbol of the horror. But whether or not worthy of the reputation, every new war weapon has been similarly received. When fire-arms were first used during the Middle Ages, there was a like vilification against the introduction of barbarian practices.

According to the most recent treatise on chemical warfare (by Lieutenant Colonel A. M. Prentiss, of the United States Chemical Warfare Service), the French were actually the first to use poison gas. Ethylbromacetate, a lachrimator or tear gas was used in French rifle grenades as early as August, 1914. Due to the shortage of bromine, a chlorine compound was substituted in November, 1914. The chloroacetone used was a toxic lung injurant.

Whatever amount of tear gas was used in the French rifle grenades and German artillery shell, real gas warfare began with the German gas-cloud attack at Ypres, Belgium, on April 22, 1915. Nearly six thousand large and small cylinders containing chlorine were installed by the Germans in their front-

line trenches. After this attack, the poison gas weapon was adopted by the Allies and by every army division on both sides.

The credit for the German gas attacks has been given to Fritz Haber, chemist, patriot, soldier and statesman, who died in exile from the ungrateful Nazi government. Although having engineered the first and other successful gas attacks, he may have been merely the scapegoat to receive abuse in the event of worldwide protest. The real instigator may have been Professor Walter Nernst, professor of chemistry at the University of Berlin. Shortly after the use of gas had been started, Nernst was decorated by the Kaiser for his "notable services," while Fritz Haber gained only the title of captain in the army and abuse in scientific circles outside Germany.

Such a possible intrigue is not new in history nor in the history of poison gas. During the Crimean War in 1855, the English Admiral Lord Dundonald, having years before noted the suffocating character of the fumes near the sulfur mines in Sicily, proposed to conquer Sebastopol through the use of sulfur fumes. The English government disapproved the measure. But the prime minister, Lord Palmerston, discussing the matter in a personal letter to Lord Panmure, wrote: "If it succeeds, it will, as you say, save a great number of English and French lives; if it fails in his hands, we shall be exempt from blame, and if we come in for a small share of the ridicule, we can bear it, and the greater part will fall on him."

The idea of poison gas warfare, however, did not originate with the English during the last century. In the war

between the Spartans and Athenians (431-404 B.C.), the Spartans saturated wood with pitch and sulfur, and burned it under the walls of cities, asphyxiating gases being liberated. More famous is "Greek fire." Its composition as far as ascertained (for its secret has been lost) shows not only readily inflammable substances as pitch, resin and petroleum but also sand and quicklime. If such were the constituents, the quicklime by being quenched in water generated enough heat to ignite the petroleum, which in burning developed sufficient heat to ignite other combustibles. The light hydrocarbons evaporating from the petroleum formed an explosive mixture with air, and in exploding developed enormous quantities of smoke and soot. Also sulfur caught fire, and in its combustion formed the asphyxiating gas, sulfur dioxide. The invention of "Greek fire" is believed to have occurred at about 600 A.D., and there is evidence of its use during the Crusades.

Twenty-six nations at the first Hague Peace Conference in 1899 pledged themselves not to use projectiles giving out suffocating or poisonous gases in warfare. Captain Mahan, the United States delegate, refused to sign, arguing that such pledges were meaningless when heavy arms and explosives were used without scruple. At the second Hague Peace Conference, in 1907, the United States delegate still refused to sign the document.

Although Germany violated this agreement with a large-scale attack, the use of poison gas by Germany should not have surprised the Allies. A deserter at Ypres, captured by the French, warned the French Divisional Commander of the impending attack, showed a primitive gas mask in support of his claims. General Ferry, believing the story, warned officers in the neighboring sectors and his superior officers. The latter ridiculed Ferry for believing the story and laughed at his suggestions that

the German trenches be shelled in order to destroy the cylinders, and that the number of men in the front-line trenches exposed to the danger be reduced.

Besides the deserter's story the Allies had sufficient basis on which to expect a gas attack. Trench warfare and the power of modern impact weapons had brought a deadlock on the Western front. Gas had to be used in order to restore movement in battle, permit tactical maneuvers and open the way to victory for one side or the other. And gas was the weapon most available to Germany. Preceding the war, its chemical industry had been developing to an amazing extent. In 1913, there were nearly fifteen thousand chemical factories in Germany, many of which were in the dye industry. In 1913, Germany produced three fourths of the total world output of dyes and at the same time more than 85 per cent. of the dye-intermediates. A few simple chemical operations changed many dyes and dye-intermediates into poison gas chemicals. Hence the military importance of the dye industry. Also its mobilization for war purposes in Germany was simplified by the corporate structure. The major portion of the industry was controlled by a holding company, the *Interessen Gemeinschaft Farbenindustrie*, and manufacturing activities were directed from a central office in Berlin.

With such tremendous resources for poison gas, Germany lost the war. The possibility of victory through its use was lost when Germany failed to produce greater and more frequent gas attacks when the Allies were unprepared, when defense measures were negligible. After the introduction of masks, gas became a very weak weapon.

Only very few chemicals are suitable for use in poison gas warfare. In the World War, over three thousand chemical compounds were selected and investigated from the approximately four hundred thousand known. About thirty met

requirements for actual use and only six were extensively employed by Allied and Central Powers.

To-day the list is probably not larger, because a chemical to be used in gas warfare must meet other requirements besides being poisonous. It must be cheap, easy to manufacture, chemically stable and capable of vaporization. Very few compounds vaporize under ordinary conditions, or conditions on the battlefield. All the light molecules which vaporize are already known, and there is ample protection against the poisonous ones. Whatever the possibility (known to be very small) for the discovery of heavier, vaporizing molecules to be used as poison gas, protection is at hand. Charcoal can absorb such regardless of the composition.

As a poison, a gas is usually classified as either one of five: Lachrimator or tear gas, sternutator or sneeze-producer, lung injurant, vesicant or blister-producer, and nerve poison. When it is capable of being in many classes, the chemical gains favor for use. Both multiple effectiveness (in more than one class) and toxicity is found in phosgene, which accounted for 80 per cent. of the gas fatalities in the World War. Mustard gas, also deadly and multiply effective, was used during the last stages of the war. It was discovered after gas masks had been introduced, when German chemists sought either a lung injurant which would penetrate the mask or an entirely new type of gas which would attack other parts of the body. The result was mustard gas and diphenyl-chlorarsine. These were mainly vesicants as are more recent discoveries: Lewisite, methyldichlorarsine and dibromomethyl sulfide. Protection for the entire body must be had to guard against vesicants, and every modern army has such protection.

The same can not be said for civilians. Outfitted with masks, they are immune to all gases save vesicants. For this

reason, such gas attacks would seem to have a chance for use in the present conflict. But neither of the belligerents will care to initiate the weapon as long as the possibility of reprisal exists.

If and when Germany can severely incapacitate Britain's chemical industry, or *vice versa*, a mustard gas attack would be "safe" for the winning side. The fear of a retaliation would then be absent. That the chemical and not the aircraft industry can be put out of action is because Britain's chemical industry is concentrated in the Midlands, while Germany's is mainly in the Rhine valley. Bunched targets make for easier bombing.

The manner of dispersing the gas must then be solved. In the last war, gases were released with shell and grenade fire and through cylinders encased in dug-outs. To repeat this procedure, Britain must invade the continent or Germany go over to England.

The release of gas through airplanes was tried by the Italians in their conquest of Ethiopia, against unprotected combatants. The same lack of wind and general climate conditions which the Italians found does not prevail in the European theater of war. New methods of airplane dispersal must therefore be found. Also air mastery must be gained. And with the latter, the necessity of a vesicant attack almost vanishes.

Should either side have control of the air, with the other refusing to surrender, vesicant attacks still seem unlikely. Britain will want to rely more upon arousing the conquered peoples of Europe. Besides alienating world opinion, gas attacks will not serve this end. Germany, too, will want to avoid the indignation of non-belligerents and not give her subjected nations more cause for discomfort. If a victory can be had through continued bombing, through invasion, through propaganda, through a war of nerves, why should gas be employed?

BOOKS ON SCIENCE FOR LAYMEN

TIME AND MYSTERIES¹

THIS second volume of the lectures given at New York University on the James Arthur Foundation maintains the high standard of its predecessor. The deed of gift allows a wide range of subject, which is well illustrated by the four contributions here assembled. Professor D. W. Hering, of New York University, discussing "The Time Concept and Time Sense among Cultured and Uncultured Peoples," draws upon his own memories of almost eighty years before, when the time of an evening meeting was posted at the village store as "early candle-light," speaks of the gradual development of an accurate sense of time as life became more complex, and takes advantage of the knowledge gained as curator of the James Arthur Collection of clocks and watches to tell the tale of the misfortunes which beset Galileo's early attempt to construct a pendulum clock.

Speaking to the title, "What is Time"? W. F. G. Swann makes bold to take his hearers into the "Torture chamber" (his own phrase) of relativistic theory. Under his guidance, the visit has no terrors. Those who know him will anticipate, and all will welcome, the accuracy and lucidity of his exposition, and the epigrammatic wit which we have learned to expect from him is there in full measure. For example, after explaining why *each* of two observers in relative motion will conclude that the other's clocks run slower than his own, he sums up: "In fact, my address is longer to everybody else than it is to you. Think how fortunate you are."

The third lecturer, John Dewey, enters quite a different field with "Time and Individuality"—which makes his contribution of exceptional interest to one who,

like the reviewer, has habitually to deal with the physical aspects of time. "Temporal seriality" says he "is of the very essence, then, of the human individual. It is impossible for a biographer in writing, say the story of the first thirty years of the life of Lincoln, not to bear in mind his later career."

The much-debated question whether some degree of similar seriality—some change and development with time—is to be found in the elements of physical nature, is clearly put. Without dogmatizing on its answer, Professor Dewey says: "Since it is a *problem* I am presenting, I shall assume that genuine transformations occur, and consider its implications." With the philosophical conclusions concerning contingency we may not all agree. But he has the great advantage of dealing with matters which bear on life and action. From his conclusion we quote: "It is easy in the present state of the world to deny all value whatever to the idea of progress, since so much of the human world seems bent on demonstrating the truth of the old theological doctrine of the fall of man. But the real conclusion is that, while progress is not inevitable, it is up to men as individuals to bring it about." These words were spoken three years ago. They have added force to-day.

Arthur Compton, speaking of "Time and the Growth of Physics," returns us to the realm of abstract thought, and hence inevitably to the consideration of relativity—which, in one aspect or another, none of his three predecessors had been able to escape—but returns to psychology, nay, to the higher criticism, before the end. "We frequently comment that rapid transportation has greatly shortened distance. It would be equally true to say that our days have been lengthened because so much more hap-

¹ *Time and Its Mysteries*. Series II. \$2.00. 1940. New York University Press.

pens to us. Did not the Israelites declare that Joshua had stopped the Sun and Moon as they were chasing the Philistines? So much happened that day that only thus could its increased length be described."

It seems to be as hard to keep psychology out of a discussion of time as to exclude relativity. It is partly, though not wholly, because they were not kept out, that this excellent little book offers so much in the way of enjoyment, as well as illumination, to its readers.

HENRY N. RUSSELL

A BIOLOGIST LOOKS AT SOCIETY¹

WHAT constitutes adventure? For one it may be exploring new countries and discovering new races and previously unknown cultures, but for Dr. Haldane adventure lies in his scientific work, for there he can learn new truths and see how they can be applied to human welfare. He is not one of those scientists who, as he says, "contrive to live in little worlds of their own, cut off from the big world. Or rather who contrive to think that they do. . . . I have never held it, but since I began to study the application of scientific method to the development of societies, I have certainly felt more justified in my attempts to popularize all kinds of science."

The first of these essays, for this is a collection of essays which have been published in magazines from 1932 to 1939, treat of such unsolved problems of science and everyday living as the weather, the composition of the earth and the sun, how health may be bettered, as well as the problem of life itself and its inevitable partner, death. He next shows how science has approached problems in the past, choosing as his illustration the problem of respiration under high pressures, a problem with which he has worked directly.

¹ *Adventures of a Biologist*. J. S. B. Haldane. vii + 281 pp. \$3.50. 1940. Harper and Brothers.

However, by far the most interesting parts of the book are those chapters in which he tried to apply scientific principles to society and to governments. He discusses present-day conditions, those in 1939, using England as his example. He is very frank in his criticisms and points out weaknesses and dangers which to-day are very evident. It is easy to see why many would object to his ideas. However, his criticisms are constructive, for he tells what he thinks must be done to correct conditions if the world of the future is to be organized along really scientific lines, lines which are at the same time truly humanitarian.

We may not all agree with his conclusions, but his ideas are stimulating and, even more important than the ideas themselves, is the method by which he arrived at them. I am sure that we will all agree with him in the statement that "we need more science, not less, and science applied not only to certain branches of production, destruction, and medicine, but to human life as a whole." All in all the book is stimulating and well worth reading.

D. B. YOUNG

FIGHTING THE FUNGI THAT ATTACK MAN'S FOOD SUPPLY¹

GIVEN an author who has written two successful novels and whose vocation is the chemical control of fungi, one might expect a popular book on fungous diseases of plants that would be readable and interesting to the layman as well as to those engaged in repelling the attacks of fungi on plants. In this book, E. C. Large fully lives up to this expectation. He has written an interesting and spicy account of the history of phytopathology by carefully selecting the phases of its development that have an appeal to the general reader without, however, sacrificing scientific accuracy and complete-

¹ *The Advance of the Fungi*. E. C. Large. Illustrated. 488 pp. \$4.00. 1940. Henry Holt and Company.

ness. He has also discussed fully some of the most sensationally destructive diseases. It probably will be news to most laymen that the potato-blight fungus was the chief cause of the great famine in Ireland near the middle of the 19th century. As the author states, "By destroying the stable food supply of a human society, already very sick from economic causes, it brought about more of death and suffering than any other disaster since the Napoleonic wars." As suggested by this quotation, the author has stressed the effect of plant diseases on human affairs and what man has done to overcome them.

Although the author is an Englishman, his point of view is world-wide. His discussions include some of the principal diseases affecting American agriculture, and the work of American investigators is highly praised. One chapter is even headed "The Lead of the U. S. A." In addition to fungous diseases in the narrow sense, there are also interesting discussions of bacterial and virus diseases. The author also gives the reader some idea of the methods used in discovering the causes of plant diseases and the establishment of preventive measures. The steps leading to discovery of Bordeaux mixture and its development by Millardet are told in a way that should appeal to any one interested in how epoch-making discoveries come about. Equally interesting are the chapters on new sprays for preventing fungus infection and efforts to obtain resistant or immune plants.

Most American investigators would probably consider the author overly optimistic regarding copper substitutes for Bordeaux mixture. Although there are good illustrations of fungi and diagrams showing their life cycles, one misses the excellent half-tones of the diseased plants or plant parts that are found in such

British books as Rolfes's "Romance of the Fungus World" and Wormald's "Diseases of Fruits and Hops." Surely a reproduction from a photograph would give the reader a much better idea of a scabby apple than the drawing shown as Fig. 48. An American author would probably have included the devastating chestnut blight that has eliminated the chestnut as a forest tree in the United States, and the brown rot disease of stone fruits that annually causes heavy losses in this country, but these are omissions of slight importance. They would only be additions to the other thrilling tales of man's fight to save his timber and his food supply.

This sprightly and beautifully written book on the major accomplishments of the science of phytopathology should not only be intensely interesting to the layman, especially the agriculturist and the historian, but it should give the professional phytopathologist a pride in his science and its founders and should be a source of inspiration, particularly to the younger workers in this field.

JOHN W. ROBERTS

DEALING WITH HYPNOSIS¹

HERE is another book dealing with the more superficial aspects of hypnosis. This differs from the others only in its magic repetition of the phrase, "autonomic nervous system," by which the author would explain hypnosis and also "hysteria . . . , psychoanalysis, Christian Science, and other forms of faith-healing." Such an approach is particularly unfortunate to-day when hypnosis is being revived for important new research on the dynamics of personality and there is a real need for a comprehensive survey of the field.

LESLIE H. FARBER

¹ *Scientific Hypnotism*. R. B. Winn. 168 pp. \$1.75. 1939. Christopher Publishing House.



London p.

From an Original in the possession of D. Mead.

Ch. Vertue del. 1728

THE PROGRESS OF SCIENCE

ROBERT BOYLE, 1627-1691

ROBERT BOYLE died two hundred and fifty years ago; yet his name is familiar to every student of elementary physics because he discovered a famous law that bears his name. He found by experiments that the pressure of a gas upon the walls of a retaining vessel varies inversely with its volume, provided its temperature is kept constant. This law and that of Charles, with the slight corrections they require for large changes in pressures and temperatures, were essential steps toward the vast scientific generalizations comprised in the molecular structure of matter, the kinetic theory of gases and the kinetic nature of heat energy.

Boyle was born when rapidly expanding science was having profound effects upon all the realms of thought. Magellan had sailed around the earth (1518-1521), Copernicus had published his heliocentric theory of the solar system (1543), Tycho Brahe (1546-1604) with scrupulous care had observed and recorded the motions of the planets, Kepler (1571-1630) had proved that the planets revolve about the sun in elliptical orbits, and Francis Bacon (1560-1626) had published his great discussion of scientific methodology.

When Boyle was born young men had been studying at Oxford and Cambridge for more than three hundred years, printing with movable type had been practiced for more than a century, Shakespeare (1564-1616) had written his immortal plays, the Gregorian calendar had been established (1582) and the King James translation of the Bible had been published (1611). Science was on the march, but it did not march alone. The human mind was moving in many columns.

Robert Boyle, the fourteenth child of the great Earl of Cork, was born at Lis-

more Castle, in Ireland, on January 25, 1627. He was a precocious child, learning to speak French and Latin in his early years and entering Eton at eight. At eleven he was traveling with a French tutor on the Continent, and at fourteen he was studying under Galileo at Florence. At seventeen he went to London and there dedicated his life to science. He soon became a member of the "Invisible College," an organization of young men who were devoting themselves to "the new philosophy." In 1663 the Invisible College evolved into the Royal Society of London for Improving Natural Knowledge, in the charter of which King Charles II named Boyle a member of its Council. In 1680 Boyle was elected president of the Royal Society, but he declined to accept the honor because of his scruples about taking an oath. A little over a century later the Invisible College and its evolution into the Royal Society of London was interestingly paralleled by the informal society Benjamin Franklin organized in Philadelphia in 1743, and which in 1780 became the "American Philosophical Society Held at Philadelphia for Promoting Useful Knowledge," to give it its complete original name.

Boyle published his famous law on gases in 1660. He was, however, more interested in chemistry than in physics, and in 1661 published a book entitled "The Sceptical Chemist." Hoping to be able to transmute metals, he was instrumental, in 1689, in getting the repeal of a statute of Henry IV against multiplying gold and silver. To-day twenty thousand tons of gold ingots lie buried in Kentucky, unused and perhaps never to be used except for industrial purposes. In the field of physics, Boyle investigated the role of the air in propagation of sound, the expansive force of freezing

water, the specific gravities and refractive indices of several important substances; in the field of chemistry he investigated the chemical nature of combustion and respiration. When he took up problems in physiology he was hampered by the "tenderness of his nature" which kept him from making dissections.

There was another side to this talented and versatile Irishman—he was greatly interested in theology, so much that he would have been made provost of Eton in 1665 if he had taken orders. He

learned Hebrew, Greek and Syriac in order that he might pursue his scriptural studies in the original languages. In spite of this he spent large sums for translations. In his will be founded the Boyle Lectures, which were established for the purpose of proving the truth of the Christian religion against "notorious infidels, viz., atheists, theists, pagans, Jews, and Mohamedans," with the proviso that controversies among Christians should not be mentioned.

F. R. M.

RESEARCH CONFERENCES IN CHEMISTRY AT GIBSON ISLAND

In each of the past four summers Dr. Neil E. Gordon, secretary of the section on chemistry of the American Association for the Advancement of Science, has organized and conducted special research conferences on chemistry at Gibson Island, Maryland, under the auspices of the Association. These conferences have increased so rapidly in size and impor-

tance that the association has recently purchased a fine property on Gibson Island to give them a permanent home. This purchase was made possible by contributions from industrial laboratories who had sent one or more of their staff members to the conference.

For many years biologists have had laboratories for summer use at various

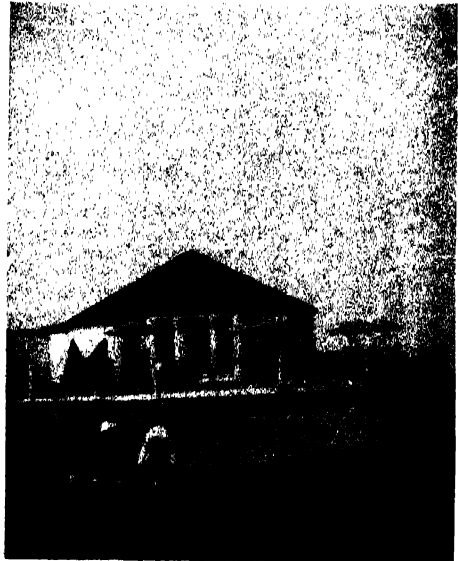


GROUP OF CHEMISTS IN FRONT OF THE CONFERENCE HOUSE
AT GIBSON ISLAND WHO ATTENDED THE CORROSION CONFERENCE IN AUGUST.

favorable locations. Research workers from many institutions have gathered at them, often year after year, to avail themselves of the exceptional opportunities offered and especially to confer with their fellow scientists. The rapid progress made in the biological sciences undoubtedly owes much to these summer laboratories. The geologists conduct field excursions and the astronomers go long distances, perhaps half way around the earth, to observe eclipses. In all these cases the scientists go to places where the material exists in which they are interested. The chemists, in the Gibson Island conferences, leave their chemicals and their laboratories and go to a place having many attractions during the summer—golf, tennis, bathing, yachting and prevailing fresh breezes from the Chesapeake Bay.

Chemists, however, are no more given to levity than their fellow scientists in other fields, as the routine of their life at Gibson Island will illustrate. Each of their conferences is devoted to a single well-defined subject and continues for five days, Monday to Friday, inclusive. For example, the eight conferences held this past summer were devoted to such subjects as Catalysis, Vitamins and Photosynthesis. All the scientific programs are held on a large screened veranda of the property which has recently been purchased by the association. Each session begins at 10 o'clock in the morning and continues until about 12:30. The program, which has been planned by a committee of experts in the field, consists of only one or two papers, leaving the remaining time for discussion. The meeting adjourns for luncheon at the Gibson Island Club. There are no formal scientific programs in the afternoon. The evening programs, which are similar to the morning program, continue until—well, until they stop, perhaps at midnight.

As necessary as laboratories and equip-



PAVILION ON THE BEACH



DR. NEIL E. GORDON

UNDER WHOSE DIRECTION THE CONFERENCES ARE
CONDUCTED, STANDING IN FRONT OF ST. CHRISTOPHER'S BY THE SEA.

ment are in most sciences, it is easy to overestimate them relative to ideas—of course, ideas that are in harmony with experience. It is in the realm of ideas that the Gibson Island conferences make their great contribution. No science owes more to ideas, mental concepts, than does chemistry, whose very elements are all wholly beyond the direct reach of the senses. Among the most interesting and remarkable achievements of the human mind is that of inferring the structures of organic molecules. And interestingly, their beauty is fully matched by their usefulness in producing desirable chemical products.

Ideas and reports of experiments are the specimens exhibited at Dr. Gordon's conferences. The ideas are not those that have long been crystallized but those that are taking form, conjectures thrown out freely among friends for criticism.

Naturally sparks of inspiration are struck when sharp minds meet sharp minds. Sometimes they suddenly throw light on a whole field, as a flash of lightning at night illuminates for the chemists on the veranda the golf course below and the bay stretching away in the distance.

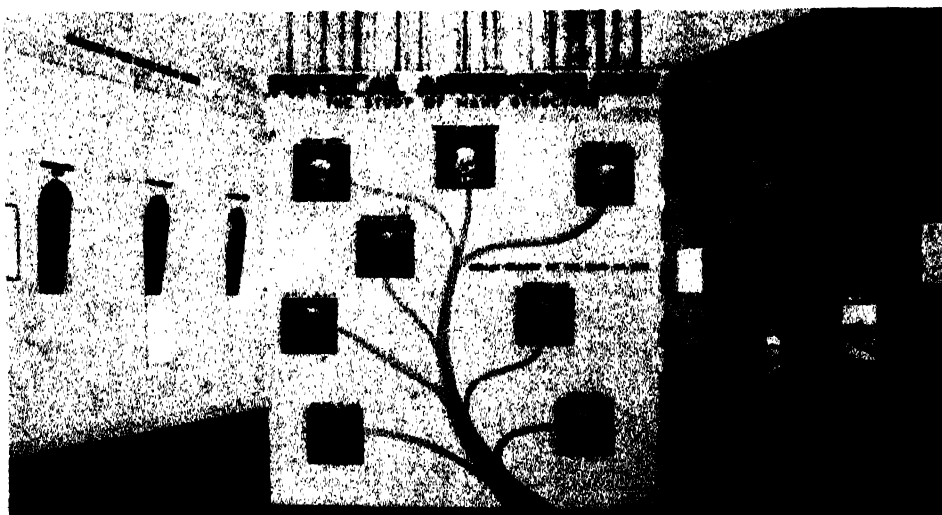
The property bought by the association consists of a large house on a lot of 3.6 acres in area, situated on a tree-covered hill, the highest on the island. It provides accommodations for between twenty and thirty scientists, the remainder of the limit of sixty for each conference being housed at the club. The island, between three and four square miles in area, is situated in Chesapeake Bay about twenty miles south of Baltimore. It is privately owned and admission to it over a causeway is only by card issued by the club.

F. R. MOULTON

PHYSICAL ANTHROPOLOGY IN THE NEW INDEX EXHIBIT OF THE SMITHSONIAN INSTITUTION

In the southeast quarter of the Main Hall of the Smithsonian Building, a

semi-circular alcove and a three-sided alcove have been arranged to portray



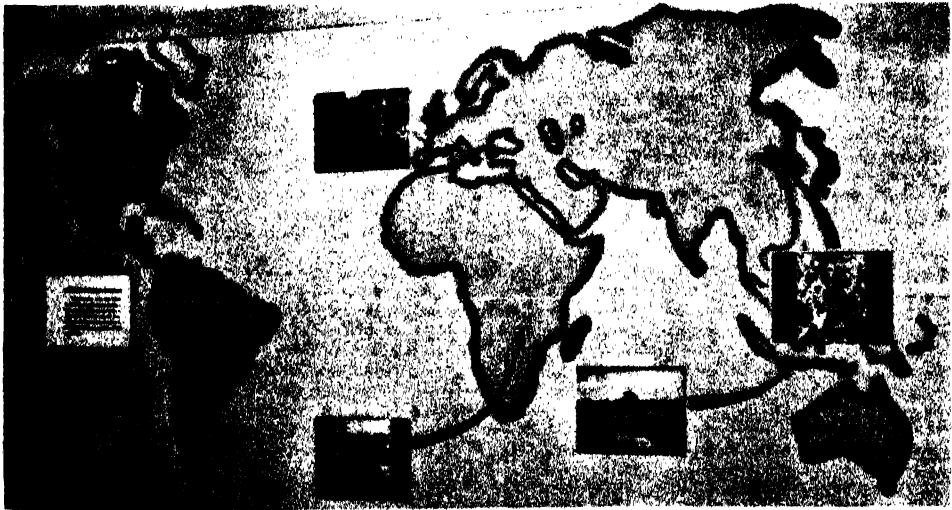
PHYSICAL ANTHROPOLOGY ALCOVE OF THE SMITHSONIAN INDEX EXHIBIT
THE EIGHT RACES OF MANKIND ARE REPRESENTED IN THE CENTRAL PANEL BY FIVE FOSSIL SKULL
CASTS AND THREE ORIGINALS.



COMPARISON OF THE THREE MODERN RACES IN THE UNITED STATES APPEARS IN THE LEFT-HAND PANEL WHICH CONTAINS PLASTER CAST BUSTS FROM THE MOST TYPICAL INDIVIDUALS OF THE INDIAN, "OLD AMERICAN" AND NEGRO RACES.

graphically the institution's activities in the field of anthropology. Adjoining the quadrant illustrating the History Section is the alcove devoted to that branch of anthropology dealing with the study of man himself, namely Physical Anthropology. This branch is concerned with the origin of man, his development from fossil to modern forms, racial classification and differentiation, race mixture and the inheritance of bodily characters and his present and future evolutionary changes. Only two phases of this subject are displayed by objects and charts of general interest.

On the central panel a hypothetical diagrammatic branch of a biological "tree" has been painted to show the theoretical relationship in the development of man from fossil to modern types. In the eight recessed boxes are displayed accurate casts of five types of early man, and three original skulls showing the main variants in modern human races. Beginning with the oldest form there are shown the *Pithecanthropus erectus* or the Java ape man, the *Sinanthropus* or Peking man, the Rhodesian man of South Africa, the Neanderthal man of western Europe, the Cro-Magnon man of France,



LOCALITIES OF DISCOVERIES OF REMAINS OF FOSSIL MAN ARE SHOWN IN PHOTOGRAPHS AND MAPS IN THE RIGHT-HAND PANEL OF THE PHYSICAL ANTHROPOLOGY EXHIBIT.

and a modern White American, a Yellow-brown (Mongol) and a Black (Negro).

On the panel to the right is a flat projection in color of the various continents, with arrows pointing to the locations from which four of the aforementioned fossil forms were recovered. The slightly recessed transparencies on this panel illustrate excavations at Choukoutien near Peking, China, which yielded the *Sinanthropus*; the site of Bengawan River, near Trinil, Java, which gave the *Pithecanthropus*; the Broken Hill mine of Northern Rhodesia, Africa, where the "Rhodesian" skull was found; and the cave of La Chapelle-aux-Saints, France, where one of the already numerous remains of Neanderthal man was recovered.

The label between the continents of North and South America indicates that extensive search in the New World has failed to reveal physical remains of early man comparable in primitive form to those of the Old World. It is now generally believed that the original migrants to the New World were essentially of the modern form.

The studies in physical anthropology extend not only to the skeletal remains of man, but where possible also to the living. The panel to the left illustrates a comparison of the three main modern races in America. In the recessed niches

are shown faithful plaster busts made from living individuals of an American Indian (Sioux), an "Old American" White and an American Negro.

In the study of the living, as well as that of the skull and other skeletal parts of the human body, numerous measurements are usually made. These measurements and the landmarks used (i.e., the points at which the measurements are taken) have been standardized to a large extent by international agreement, so that they may be taken with similar instruments and in the same way the world over, and thus assure data that can safely be used for human comparisons and prove of scientific value. The measurements supplement the visual and other instrumental observations; the ultimate object of all such research is to learn thoroughly everything that relates to the physical man and, with this knowledge as a basis, assist in his future progress.

The Division of Physical Anthropology in the U. S. National Museum has a classified skeletal collection numbering 37,000 specimens, which has long been used by anthropologists, medical men and dentists for their studies. It excels in well-documented series of American Indian and Eskimo material, and includes a rich and highly valuable human, ape and other animal brain collection.

FRANK M. SETZLER

X-RAYING A MUMMY AT THE FIELD MUSEUM OF NATURAL HISTORY

HARWA, a Twenty-second Dynasty Egyptian mummy, was keeper of the storage houses on the estate of one of the temples of Amon, the chief God of the Empire, some 2,800 years ago. Now, Harwa is the only adult-sized person who is publicly fluoroscoped every day. Loaned by the Field Museum of Natural History for exhibition at the New York World's Fair, he was seen by millions of people. The physical set-up of the ex-

hibit, in which the mummy is shown, was a gift from the General Electric X-ray Corporation, whose engineers and technicians assisted in installing it in a special chamber in the Hall of Egyptian Archeology.

When visitors enter this chamber they see Harwa in his external mummy wrappings illuminated by amber spot lights. The lights fade out and the fluoroscopic screen slides into place. After a short



THE MUMMY IN THE X-RAY CHAMBER
BEFORE THE FLUOROSCOPIC SCREEN MOVES IN
FRONT OF THE FIGURE.



X-RAY IMAGE OF THE SKELETON
OF THE MUMMY AS IT APPEARS ON THE FLUORO-
SCOPIC SCREEN.

interval of darkness to accommodate the eyes, the x-ray is energized and projects the image of Harwa's skeleton upon the screen. The cycle is 40 seconds and is repeated automatically throughout the day. There is also selective control for use when visitors are few in number—then they may themselves operate the exhibit by pushing a button.

The machine used is a therapy apparatus with a Coolidge tube unit on a fixed mount. As the anode angle of this tube permits field coverage of a diameter equal to the distance, the "treatment cone," a pyramidal lead-lined box, is 160 cm long—Harwa was shorter in stature than the average Egyptian. The fluoroscopic screen is mounted behind lead glass for the protection of visitors.

A series of stereoscopic radiographs made of Harwa through the courtesy of the University of Chicago's medical department, and their study by a highly qualified roentgenologist, fail to reveal the cause of death. The twelfth left rib is missing, opening the question as to whether it may have been removed by the embalmer, or was congenitally absent.

There is no evidence of osteoarthritis. This is unusual among adult Egyptians, as their daily life was so intimately bound up with the River Nile. Irrigation, fishing and boating all called for frequent contact with the water, and contrary to the general impression the climate of Egypt is often disagreeably cold. There is a possible indication that Harwa may have had an alveolar abscess about the anterior root of the lower right first molar. The average Egyptian had excellent teeth, dental trouble being largely confined to the upper classes with their pampered diets. The examination confirms the conclusions of archeologists that the mummy is that of a male, and that Harwa was between 25 and 40 years of age at the time of death.

The study by a roentgenologist, and the exhibit of Harwa at Field Museum, both using the most modern of medical aids, make a link with the beginnings of medical science. Doctors were a recognized part of the ancient civilizations of the Near East. By 2000 B.C. surgical practices were covered by law. A section of the Code of Hammurabi, King of Babylon, states: "If a physician make a deep incision upon a man (perform a major operation) with his bronze lancet and save the man's life; or if he operate on the eye socket of a man and save that man's eye, he shall receive ten shekels of silver." However, the law continues, if the operation were unsuccessful and the patient should die or lose his eye, the physician's hand would be cut off. Rates varied with the social scale, just as some physicians to-day base their charge on the patient's ability to pay. The common man was charged only five shekels for a ten-shekel treatment, and the slave but two shekels.

From Egypt, at about the same period, come surgical texts dealing with examination, diagnosis and treatment. Splints were employed for broken bones, and in severe cases the patient's body was immobilized in the correct position by casts of mud. The custom of mummification provided aids for the skill of the surgeon. The embalmers' fine linen wrappings made excellent roller bandages, and wounds were drawn together with adhesive tape. The use of stitching to close large incisions was used on the dead, and may have been employed on the living. Later, in the third century B.C., a great medical school developed in Alexandria. From this Egyptian school came two great Greek physicians: Herophilus, father of anatomy, and Erasistratos, father of physiology.

RICHARD A. MARTIN

STATIC ELECTRICITY AND AUTOMOBILES

STATIC electricity means little less to the layman than a nuisance in his radio reception, or a plaything for him to draw sparks from door-knobs or to display his "magic powers" by lighting a gas burner from his knuckles. Since technical literature, beyond the covers of the text-book, is practically destitute of information on the generation and behavior of static electricity, relatively few are aware of the fact that each year it takes a considerable toll of life and an economic loss totaling many millions of dollars results annually from its fires and explosions.

Static Electricity in Industry: In industry, electrostatic potentials may be encountered as high as 75,000 volts. The more common sources of such generation are rapidly running belts driving machinery, belt conveyors employed in granaries, coal handling or package conveyance, compressed gases escaping from jets or nozzles, paper running over rolls during its manufacture or printing, fluids, such as petroleum distillates, flowing rapidly through pipes or hose lines into terminal tanks, or rubber-tired vehicles in running along the highways. Since the electrification of rubber-tired vehicles has become particularly hazardous in the haulage of inflammable substances such as volatile petroleum distillates and explosives, the author undertook an experimental study of static electricity to determine how it was generated and stored on a vehicle, how it subsequently behaved and how its control and harmless discharge might be effectuated.

Electrification by "Contact Difference of Potential": Experiment has shown that when two unlike substances are pressed firmly together, such as rubber tires on the roadway, electrons escape from the molecules of the concrete or asphalt and pass into the rubber treads of the tires. These electrons are known

to be the smallest indivisible particles of negative electricity, and they are normally constrained to their orbits or shells within the atoms by the intra-atomic electrical forces which exist in the neutral atom between them and the equal number of positive particles which are compacted into the nucleus.

So, when these unlike substances, the tires and the roadway, are in contact with each other, an unbalance of the intra-atomic forces occurs at their boundary surfaces which thereby permits a relatively small proportion of the billions of these electrons to pass from the roadway into the tire treads. In this way a difference of potential is established between the two contacting substances—the negatively charged tires and the

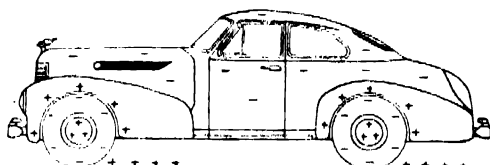


FIG. 1. DISTRIBUTION OF ELECTRIC CHARGES

ON AN AUTOMOBILE BROUGHT ABOUT BY THE PROCESS OF ELECTRIC CONDUCTION.

positively charged roadway. Its value, however, is small, being of the order of a fraction of a volt. This principle by which voltage is produced is properly known as "contact difference of potential," a concept none too well understood as yet, and commonly, though erroneously, referred to as "frictional electricity."

In insulating materials, as these are, the electrons are more or less rigorously constrained from flowing readily from one place to another. In conductors, on the other hand, such as metals, electrons migrate freely from place to place, a property from which they gain their name of "free electrons."

The two charged surfaces, the tire treads and the roadway, separated as



FIG. 2. A PASSENGER CAR BEING TESTED FOR ELECTROSTATIC VOLTAGE

they are by about $1/100,000,000$ th of an inch, or the approximate diameter of a molecule, constitute an electrical condenser. The capacity of this condenser to store electrical charges increases directly with the area of the charged surfaces and with the voltage between them, and inversely with the distance separating them. If the surfaces, having been charged, are now appreciably separated, the voltage between them is found to increase as their separating distance increases. This is the reason why such a small contact potential difference as a fraction of a volt will multiply into many thousands of volts when the surfaces are separated by, say, several inches.

Electrifying Rubber-tired Vehicles: As each unit of area of the electrified tire treads separates from its ultra-microscopic closeness with the charged pavement, as the wheels roll along the highway, the voltage between the two increases greatly. The average voltage between the tire tread and ground, however, can only increase when additional charges are imparted to the treads, and, as will be seen from the results of test, this condition depends essentially on the speed of the vehicle, on the degree of tire

inflation, on the value of the tire loads and on the grades of the roadway.

The process by which the body of the vehicle is ordinarily electrified from the charged tires is called "electric induction." The high electrification possessed by the tire treads causes the free electrons in the closely adjacent metal parts, the fenders and wheels, to be repelled to the more remote areas of the car body as the so-called "free charge." An equal amount of positive charge is then left behind on the fenders and wheels as a so-called "bound charge." It is held there, separated from the negative charge on the tires, by the ultra-high resistivity of the side walls of the tires or of the intervening air. This normal distribution of the electric charges on a rubber-tired vehicle by the process of electric induction is shown in Fig. 1.

Testing on the Otis Proving Stand: The electrification of car bodies was found to be affected by humidity, air and tire temperatures, tire inflation and loading, condition of the tires and roadway, speed of travel and the grades of the roadway. Since these variable factors could not be individually controlled during tests on the highways, an Otis Proving Stand, a high-speed chassis dynamo-

meter, was eventually employed, through the auspices of the Brooklyn Edison Company and the Gulf Oil Company, in obtaining the final quantitative results. An inspection of Fig. 2 shows a vehicle operating on the dynamometer during one of the tests. The drive wheels of the vehicle run on steel drums which may be variously loaded to simulate driving conditions on level roadways or on up-grades. A car may operate on the test stand over a speed range to 70 m.p.h. The voltage, generated between the car body and the "grounded" drums, was measured by means of an electrostatic voltmeter which was provided with four scales, the highest reading to 30,000 volts.

The Characteristics of the Generated Voltage: Under the conditions of no load on the car, such as running along a level roadway, the voltage of the car to ground was found to vary with the speed—linearly at the lower speeds and approaching a constant voltage at high speeds. Also the voltage was found to depend upon the degree of tire inflation, being higher for the higher pressures. The variation of voltage with speed is shown in Fig. 3 for three values of tire inflation for a passenger car and similarly for a 5-ton truck. From these and other tests it is estimated that, under favorable conditions, the voltage generated by heavy, high-speed trucks or buses will range between 30,000 and 40,000 volts.

Additional tests were made to determine the influence upon the generated voltage of a vehicle under load, such as operating on up grades of increasing steepness. These loads are specified by the driving force, or "tractive effort," in pounds push at the treads of the rear driving wheels. These tests showed that the voltage increased linearly with the tractive effort, as may be seen in Fig. 4. The steepness of these curves is considerably greater for the truck than for the passenger car, a condition which con-

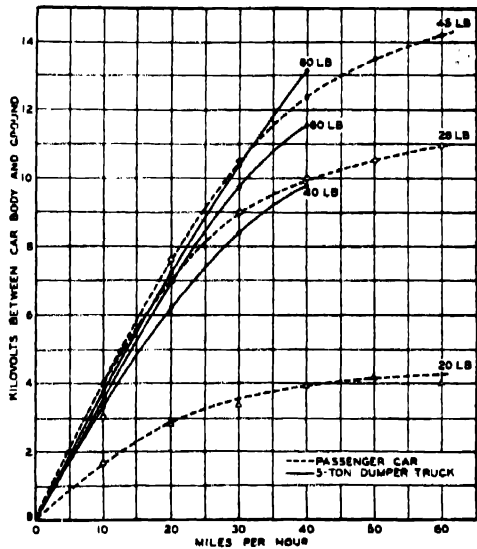


FIG. 3. EFFECT OF SPEED ON VOLTAGE FOR THREE VALUES OF TIRE INFLATION IN THE CASE OF A PASSENGER CAR AND A TRUCK.

forms with the principle of "contact difference of potential." Since the push on the treads of the truck tires is greater than for the passenger car, because of the much greater weight of the former, the surfaces of the tire treads must tend to enmesh with the roadway in more in-

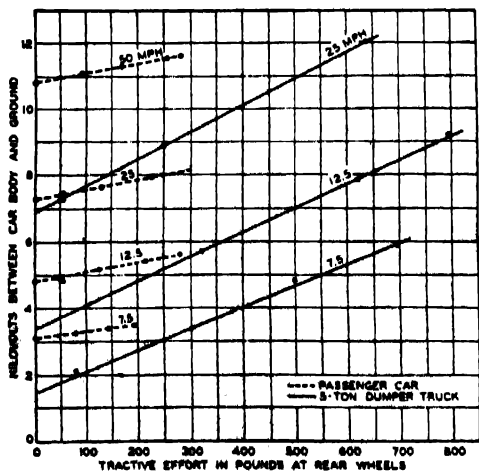


FIG. 4. VARIATION OF VOLTAGE WITH LOAD

AT FOUR SPEEDS FOR A PASSENGER CAR AND THREE SPEEDS FOR A FIVE-TON TRUCK.

timate contact. Consequently, more electrons are appropriated from the road surface by the tires, and thereby a higher voltage per unit of tractive effort results.

Ineffectual "Grounding" Practises: The "drag chain," as commonly seen dangling from the rear of gasoline tank trucks, has for its alleged purpose the conduction to ground of the "free" negative charges on the body of the vehicle, so as to eliminate electric sparks and thereby remove the attendant fire and explosion hazards. On a number of occasions during tests, an electrified car body showed no appreciable leakage of its charge over a period of a half hour or more, in all of which cases skid chains had been draped from both front and rear bumpers to the roadway.

Since the dry roadway presents a surface of most excellent insulating properties, obviously the charges are effectively impounded on the car body and, hence, they can not discharge to ground. These and other tests have clearly demonstrated the futility of drag chains as a means of grounding. Likewise the many other "gadgets" employed to accomplish this purpose of discharging the vehicle to ground, through the intervening roadway, including conductive rubber tires, are equally ineffective on highways for which the materials of construction and the surfaces possess ultra-high electrical resistivities.

Trends toward a solution: An effective solution of the problem of discharging electrical rubber-tired vehicles suggests

itself from a study of the various basic factors; but, under present methods of highway construction, this solution does not have an immediate or simple application.

Assume that the surface of the highway could, in some way, be made conductive, then, by using conductive rubber tires, which are now available on the market, the electric charges, if generated by the tires and stored on the car body during its operation, would flow away to ground as soon as the vehicle came to a stop. As a substitute method, but one of much less efficacy, the expansion joints as now commonly used, every few feet apart, on concrete highways, could be made of conductive composition and thoroughly grounded. By this means, the vehicle would discharge to a fairly low potential at the last ground joint encountered before its final stop. These discharge joints would likewise be required on asphalt and macadam roadways.

If the highway engineer could ingeniously formulate a conductive composition with which to face the roadway surfaces, as effectively as the research engineer has developed conductive rubber tires by "loading" the rubber with conductive carbon black, fire and explosion hazards resulting from static electricity on rubber-tired vehicles would no longer be a problem. Some study into these proposed methods might yield encouraging results.

ROBIN BEACH

THE SCIENTIFIC MONTHLY

NOVEMBER, 1941

LANDS BENEATH THE SEA

By PAUL A. SMITH

UNITED STATES COAST AND GEODETIC SURVEY

AN atmosphere suggestive of the legends of Lemuria, Atlantis and other myths of the lost continents sung by the bards of antiquity has, to some extent, surrounded studies of submarine relief. It may be that this is the natural result of the attraction of the imagination to the unknown. When one reflects how, in past centuries, the unexplored areas of the earth's surface have been peopled by strange and awful monstrosities which we now know existed only in the human fancy, it is not surprising that the human imagination has been so strongly stimulated by speculation on the forms of lands beneath the sea, as well as the forms of life dwelling within the sea. Here, as in other explorations into the unknown, the cold light of fact disperses the shadows of uncertainty; and the ocean deeps, submerged mountains and valleys, plateaus and plains, are gradually becoming known well enough through the accumulation of soundings so that we can begin to study their shapes—their physiographic characteristics—and even draw conclusions with some degree of certainty about the relations between the geologic history of adjacent land and water areas. Topographic features beneath the sea must, of course, be mapped and studied by indirect means because they can not be seen, at least not over extensive areas. The fact that they are for the most part

invisible to human eyes, and probably will remain so for some years to come, lends an air of mystery to them.

Our knowledge of the approximate limits of the great ocean deeps, extensive ridges and large submarine features of continental proportions is now fairly good. We know, for example, of the existence and even the approximate limits of the great Atlantic Ridge, the Easter Island Ridge, the Philippine Trough, Aleutian Trough and numerous other major submarine features, even though many of them are covered with at least a thousand fathoms of water. By "fairly good" is meant that it is about as complete (by crude analogy) as was the map of the continents of the world at the beginning of the seventeenth century. The International Hydrographic Bureau has done much to collect such information, and the ships of the United States and foreign navies have, by taking soundings along their routes, contributed extensively to the general knowledge of the bottom relief of oceanic areas.

In a few coastal regions where intensive charting surveys have been made by modern methods, such as those perfected by the United States Coast and Geodetic Survey, even the precise details of form are known; and it is largely upon the results of these well-sounded coastal areas that new concepts of the geologic



Coast and Geodetic Survey, Manila
GENERALIZED SUBMARINE RELIEF MAP OF THE PHILIPPINES.
THE DEEPEST SOUNDING IN THE WORLD, 35,400 FEET, WAS OBTAINED IN THE DEEP EAST OF MINDANAO ISLAND (LOWER RIGHT IN PHOTOGRAPH).

relation between continents and ocean basins are being formed. An explanation of the origin of continents and ocean basins satisfactory to all branches of earth science has yet to be made, but the development of automatic depth recorders and accurate methods of position finding at sea within the past two decades have contributed important additions to our knowledge. It is not desirable here to elaborate upon the methods of survey or the fundamental practical purpose of the surveys,

complete knowledge of which may contribute to a better understanding of that part of earth history hidden beneath the sea.

With a few exceptions it is generally assumed by geologists that the present continental masses and ocean basins have not changed much in position throughout the geologic ages since pre-Cambrian time, a matter of at least 600,000,000 years. Crustal warpings and squirmings are supposed to have spread the oceans over extensive areas of the present con-



Photo by Clarence E. Petersen, U. S. Coast and Geodetic Survey
SURVEYS OF THE SHORE PREPARATORY TO SURVEYS BENEATH THE SEA.
COAST AND GEODETIC SURVEY TOPOGRAPHIC PARTY IN TAKU INLET, ALASKA, 1937.

namely, to provide accurate and reliable nautical charts. That is a fascinating story in itself. It is, I believe, important to note that due to modern charting surveys there are few places in the world where we have better knowledge of the relief of submerged continental margins than about the shores of the United States, Alaska and the Philippine Islands. The geologic significance of the results of the surveys is an interesting and not unimportant by-product, and this note is devoted to a brief description of a few of the submarine forms, a more

tinents upon a number of occasions, forming the shallow epicontinental seas in which vast layers of sediment were deposited. These assumed conditions, based on many geologic observations and numerous lines of sound reasoning, satisfy most branches of geologic science; but there has always been some difficulty in explaining such things as the existence of many identical land-dwelling flora and fauna as well as littoral forms without some land connection in the past between the continents on which they are found. These continents are now sepa-



E. Morris, Jr., U. S. Coast and Geodetic Survey

SOUNDING PARTY IN FRONT OF TAKU GLACIER.

THE OLD HAND LEAD IN USE IN THIS PHOTOGRAPH IS RAPIDLY BEING REPLACED BY AUTOMATIC DEPTH RECORDERS. LAUNCHES ARE USED TO SURVEY THE SHALLOWER COASTAL WATERS.

rated by many miles of deep ocean waters that make an impassable barrier to the forms of life in question.

It has been concluded by geologists that world-wide changes of the sea-level have occurred several times during the last million years or so. These changes in sea-level are supposed to have been caused by the evaporation of sea water which would be necessary to account for the great ice caps of the Pleistocene epoch. Various estimates of this "eustatic lowering" of sea-level have been made in recent years, but some figure of the order of 300 feet is probably tentatively accepted by the majority.

But in the light of the new surveys, the forms of the lands beneath the sea—their physiography—seem to indicate that the ocean waters may have been withdrawn in much greater quantities and within such late geologic time as to account for the migration of certain species over "land bridges" between the continents. In some cases a change of at least 10,000 feet between sea-level and land is indicated by the seavalleys. The

weight of evidence against such a great change between land and sea is large. Existing geologic theories based upon the assumption of permanent continents and ocean basins are so firmly established that any idea opposing it encounters seas of opposition almost as vast as those of the real oceans of the earth, which have until recently hidden the important evidence now coming to light. A few of the facts in submarine physiography that support it, however, deserve mention.

It is difficult to describe submerged land forms without large maps or chart sections, but a few of the most striking examples may lend themselves to satisfactory reproduction within the limits of this journal. It must be done by contours, that is, by drawing lines of equal depth based on soundings. This is tedious work, requiring painstaking study of hundreds of thousands of soundings. Relief maps or models may be made from such contoured charts and they are usually preferred by the average reader.

It is interesting to note in passing that the first use of contour lines for repre-

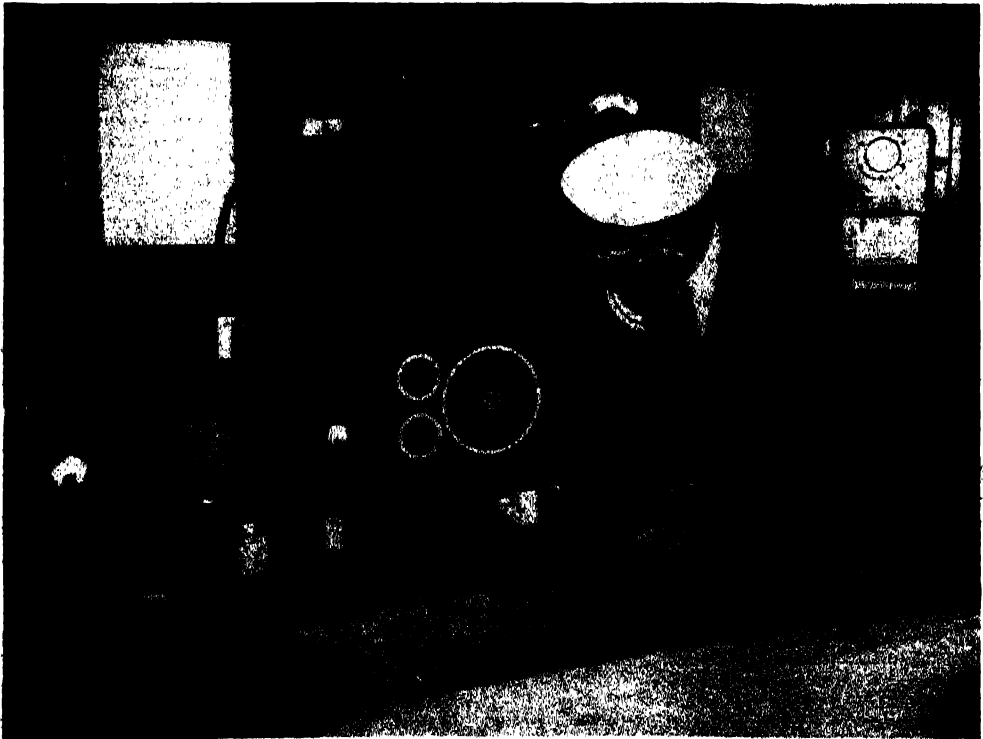
senting relief was made in delineating submarine features and not land forms above the sea. A Dutch engineer and surveyor, Cruquius, made a contour chart of the Merwede River in 1728.

In the intervening years contours have come into general use for showing land relief, but nautical charts have not until quite recently carried more than a few highly generalized "depth curves." There was good reason for this. When beyond sight of land ships could not be located accurately in position, that is, "accurately" as a surveyor defines the term; so that positions of the soundings as charted were frequently several miles away from their actual positions. Also, in order to take soundings in water deeper than about 100 feet it was necessary when using the old hand lead or deep sea lead to stop the ship and lower

a weight on a line until it touched bottom, measuring the amount of rope or wire payed out. Soundings in deep water, therefore, required so much time that up until about 1925 very few soundings had been taken in the deeper waters beyond the edges of the continental shelves. And such soundings as were on the charts, except those near shore, were subject to so much error in position that attempts to draw contours inevitably resulted in unsatisfactory generalized sketches.

Coupled with the limitations in accuracy of position and paucity of soundings was the well-established idea that all ocean bottoms were the repositories of the sediments eroded off the lands and carried into the sea by rivers for the past hundreds of millions of years.

Such "basins of deposition" must,



New York Daily Mirror

DORSEY FATHOMETER RECORDING 20 SOUNDINGS PER SECOND.
COMMANDER F. S. BORDEN READS AT A GLANCE THE DEPTH OF WATER BENEATH HIS SURVEY SHIP
FROM THE DIALS OF THE MOST PRECISE DEPTH INDICATOR YET CONSTRUCTED.

according to this idea, be characterized by the smooth, gentle slopes one might logically expect to find under such conditions. The more thorough and accurate surveys made in shoaler waters on the continental shelves near shore and within sight of land supported this hypothesis. So it was not until echo sounding was perfected and applied to marine surveying (beginning about 1926) that the true nature of deep submarine relief was realized. About the same time a method utilizing sound and radio, known as radio acoustic ranging, was being developed by the Coast and Geodetic Survey for accurate position finding out of sight of land. The past two decades, therefore, have seen the accumulation of more accurate and thorough coastal surveys than in all preceding history; and these accurate surveys with many continuous profiles obtained through automatic depth recorders have made it possible to produce contour charts of submarine relief.

Probably nowhere in the world can one find a greater variety of land forms in so small an area, both above and below the sea, than in the Philippine Islands region. The relief of the submerged areas around the Archipelago varies from the broad, flat, continental shelves less than 500 feet deep, such as the submerged platforms of Palawan Island and the numerous islands of the Sulu Archipelago, to the greatest known ocean deep, 35,400 feet, just east of Mindanao. This is about $6\frac{1}{2}$ miles deep, and it is interesting to note that Mount Everest, the world's highest peak, if placed in this abyss would still be covered by over a mile of sea water. The Sulu Sea is a mediterranean sea in that this large basin, over 17,000 feet deep in places, and about 250 miles in diameter, is cut off from the exterior seas (the China Sea to the west, Pacific Ocean on the east, and Celebes Sea on the south) by the shallow submerged edges, or rims, of the

bowl. The deepest part or threshold of this submerged rim is only about 1,500 feet below sea-level. Hydrographic surveys by the Coast and Geodetic Survey have been in progress in the waters surrounding the Islands since 1901, and these surveys, now well advanced, show many striking submarine features. A number of active volcanoes on the islands above the sea, combined with lively seismic or earthquake activity, make a complex and interesting—one might almost say exciting—geologic combination.

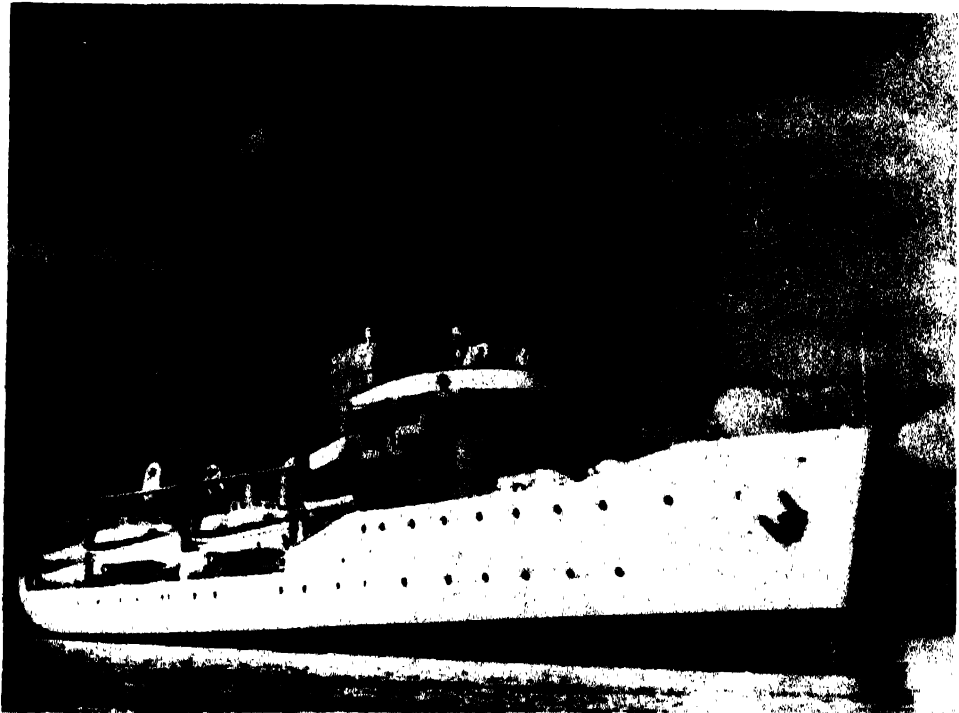
Two large drainage basins are found in the Islands. The Cagayan River on Luzon Island flows north into Babuyan Channel; and seaward from its mouth, heading almost within the river estuary, is a submarine valley cut a thousand feet down into the ocean floor. It is obviously a continuation of the present Cagayan River.

The Mindanao River is a more striking case of this type. Here the present river flows into the Celebes Sea through two prominent distributary channels, and a knoll 600 feet high separates the river mouths at the present coast line. Seaward from the present shore the hydrographic surveys show two deep well-developed seavalleys, each heading precisely from the shore at each river mouth.

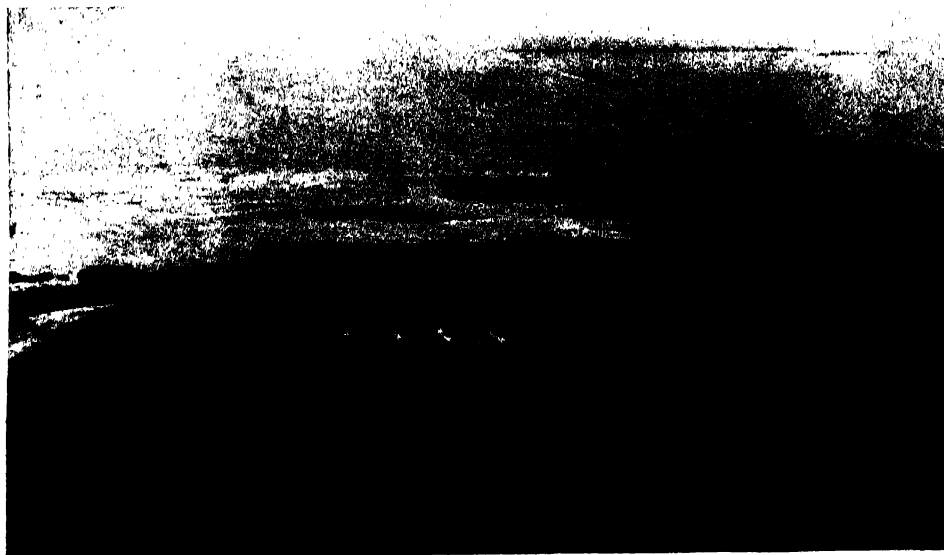
On the other side of the world the mighty Congo River of Africa, second largest river in the world, empties into the Atlantic Ocean through a long estuary, and the deepest known submarine canyon (5,000 feet) has been cut over 20 miles back into this estuary. The head of the Congo Seavalley is over 80 miles inside what is called the "edge" of the continental shelf. In still another part of the world the "Sacred River of the Hindus," the Ganges, debouches into the Bay of Bengal through a crocodile infested, jungle delta 200 miles wide, which is known locally as the Sundar-



W. Weidlich, U. S. Coast and Geodetic Survey
U. S. COAST AND GEODETIC SURVEY SHIP, IN RUDYERD BAY, ALASKA.
 SOUNDINGS SHOW THAT SUCH RUGGED LAND FORMS AS SEEN HERE ALSO EXIST MANY FATHOMS
 BENEATH THE SEA. THE VESSEL IS THE OLD "EXPLORER," NOW REPLACED BY A MODERN SURVEY
 SHIP OF THE SAME NAME.



U. S. Coast and Geodetic Survey
THE NEW SURVEY SHIP "EXPLORER"
 WITH COMPLETE SURVEYING EQUIPMENT, LAUNCHED IN 1939, REPLACED THE OLD SHIP.



W. Weidlich, U. S. Coast and Geodetic Survey

A COAST AND GEODETIC SURVEY CAMP IN SOUTHWESTERN ALASKA.
MUCH OF THE LIFE OF A COAST SURVEY FIELD ENGINEER IS SPENT IN SUCH ISOLATED OUTPOSTS
GATHERING DATA FOR CHARTS WHICH HELP MAKE COASTAL WATERS SAFE FOR NAVIGATION.



R. K. Wassche, U. S. Coast Guard

BOGOSLOF ISLAND IN ERUPTION IN 1910.
A VOLCANIC CONE WITH BASE A MILE BELOW THE SEA IS CUT OFF AT SEA-LEVEL BY WAVE ACTION.

bans. Eighty miles seaward from the shore is the edge of the continental shelf. The seavalley of this great river of Asia is cut almost 70 miles back into the shelf and at least 3,000 feet deep. It is known on British charts as "Swath of No Ground." The Indus River, 1,600 miles westward, empties into the Arabian Sea under similar circumstances and likewise a great seavalley is found off its mouth.

As for submarine mountains, a few examples are typical. A reconnaissance survey of the Gulf of Alaska, made by the Coast and Geodetic Survey ships en route to and from their working grounds during the past 15 years, shows that many large and impressive mountain

canic "Island of Mystery" in the Bering Sea just north of the Umnak Island, discloses that this small island, only about one mile in its greatest extent, is simply the top of a great volcanic cone more than five miles in diameter at the base, 5,000 feet below sea-level. This cone has been truncated by the sea to form a small submerged platform about two miles in diameter on which the island of Bogoslof stands. Each time the volcano erupts, as it has done a number of times within the historical period (since the last part of the eighteenth century), the small group of rocks forming the island are, of course, moved about on the submerged platform, causing the



U. S. Navy

BOGOSLOF, FORMERLY ERUPTING, NOW LYING DORMANT.

FROM THE AIR THIS INSIGNIFICANT ISLAND SHOWS NOTHING OF THE GREAT VOLCANIC CONE HIDDEN BY THE SEA, BUT REVEALED BY THE SOUNDINGS.

ranges break the relief of the ocean floor in the Gulf. Prior to this discovery, the bottom of the Gulf of Alaska was occasionally referred to in geologic literature as one of the flat-bottomed "ocean basins." A few profiles plotted over some of these mountains show that they reach, in some instances, heights of 12,000 feet above the surrounding ocean bottom, although the summits are often half a mile or more beneath the surface. These preliminary profiles tell the experienced student of landforms that the submerged mountains have all the general characteristics of similar mountains we can see on the lands around us.

An intensive and accurate survey made around Bogoslof Island, the vol-

canic island to change shape and position and even to disappear completely at times. Here again the "stub" of this submarine volcano is almost identical in form and size with the equivalent lower sections of similar cinder cone volcanoes—Mounts Cleveland and Carlisle, for example, in the Islands of Four Mountains, not far to the west in the Aleutian Islands.

Mendocino Escarpment, off the Pacific Coast of the United States, is probably the seaward extension of the San Andreas rift reaching offshore west of Cape Mendocino for at least 60 miles, and 6,000 feet high on the northern face. There are also numerous seavalleys off this coast, some of which are clearly the continuation of existing land drainage,



W. Weidlich, U. S. Coast and Geodetic Survey
IN MAY, 1940.

PAVLOF VOLCANO, ALASKA PENINSULA, IN MAY, 1940.
THE VOLCANIC AND SEISMIC ACTIVITY OF THE PENINSULA AND THE ALUTIAN ISLANDS ARE TYPIFIED BY THESE DORMANT VOLCANOES,
AT LEAST ONE OF WHICH (BOGOSLOF) IS BENEATH THE BERING SEA.



TYPICAL SUBMARINE MOUNTAIN RANGE IN THE GULF OF ALASKA.

VERTICAL AND HORIZONTAL SCALES ARE EQUAL.

such as the Monterey and Carmel Seavalleys. Off the southwest coast of California the new surveys show extensive areas rich in what geologists term structural forms, that is, land shapes which are the result of large movements of sections of the earth's surface. Some remarkable examples may be found offshore between San Diego and Point Arguello. This is not surprising when it is realized that the same features control or dominate the relief of the adjacent land in Southern California. Even the last region mentioned has several prominent seavalleys, and it is also notable that each of the small islands off the coast of Southern California stands on its own small submerged platform similar in depth to those in the Philippine Islands and Alaska thousands of miles distant and in widely different latitudes.

These submerged platforms are found in greater or less extent about almost every island or continent in the world, and the depths are remarkably uniform.

In the Gulf of Mexico the recent surveys show a different picture, but again not unexpected when the rather complete knowledge of the geology of the Coastal Plain adjacent to the Gulf is considered. The continental shelf here is unusually flat and smooth, and in places over 100 miles wide. The steeper declivity known as the continental slope is broken by some seavalleys, but less pronounced in character and less numerous than those of many other regions in the world. Here the landward heads of most of the submarine valleys seem to merge into the general slope between depths of 200 and 300 fathoms with a notable exception. The most important of the known sea-



W. R. Porter, U. S. Coast and Geodetic Survey

MOUNTS CLEVELAND AND CARLISLE OF THE ALEUTIAN ISLANDS.

MT. CARLISLE AT RIGHT, EXACTLY ONE MILE HIGH, IS HERE HIDDEN BY THE CLOUDS IN ALMOST THE SAME PROPORTION AS BOGOSLOF IS COVERED BY THE SEA.

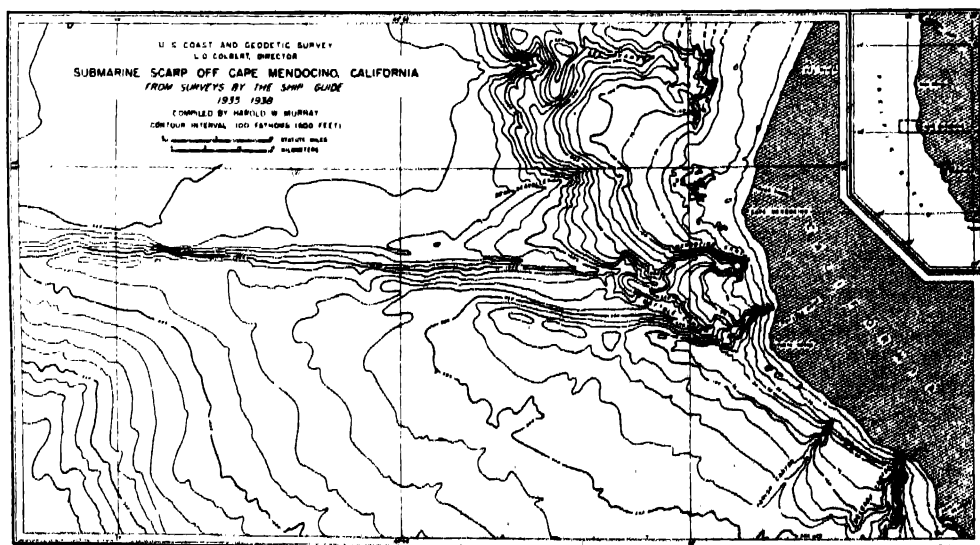
valleys in the Gulf of Mexico indents the shelf for about 30 miles just southwest of the present Mississippi River. Its exact connection in geologic time with the present Mississippi River is obscure, as is the case in other similar examples.

The continental margin of the Atlantic Coast of the United States is now well surveyed over about half of its total extent, i.e., between Cape Hatteras and Georges Bank, 150 miles east of Cape Cod. The shelf is also flat to depths of about 500 feet, but it is rich in forms similar to those being shaped by wave and tidal current forces close along the adjacent shore to-day.

The continental *slope* north of Cape Hatteras, on the contrary, is heavily eroded into many deep canyons like those made by streams running down similar steep slopes in mountainous regions on land. Outstanding of these Atlantic Coast canyons is the Hudson, 3,600 feet deep in its deepest cut, which is connected to the present Hudson River by a shallow submarine channel extending

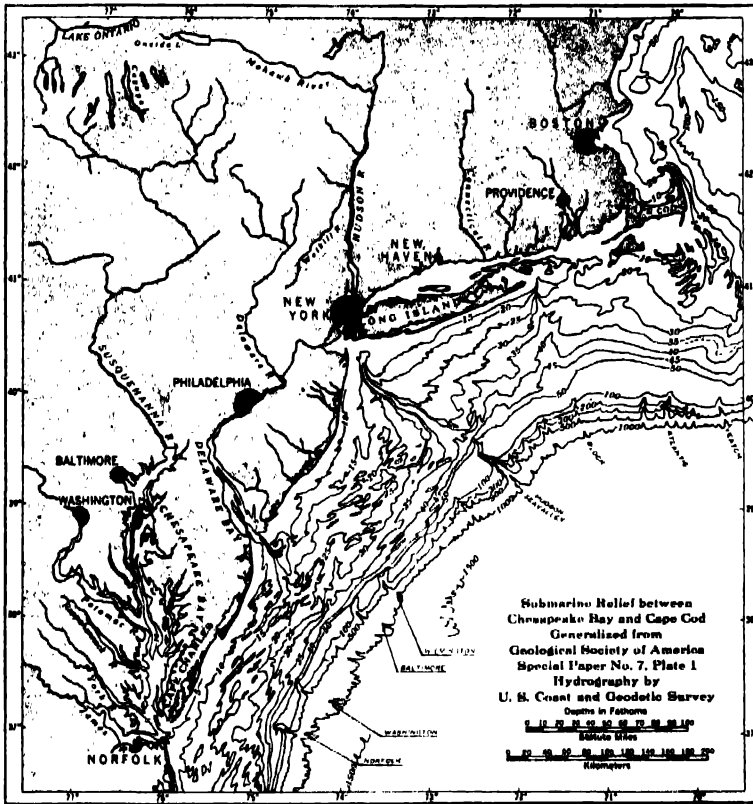
100 miles across the shelf. The form of this shallow channel resembles the channels now submerged in Chesapeake and Delaware Bays to a striking degree. The differences in characteristics of the channel or shelf features and those of the slope are apparent from profiles registered by the depth recorder as the surveying ship crossed the features. Between the seaward end of the Hudson Channel and the deep seavalley or canyon cut 17 miles back into the continental shelf is an old delta covering over 500 square miles and at a depth of about 43 fathoms (258 feet).

The surface of the continental shelf near Nantucket Island, where strong tidal currents run continuously, is ruffled by large "submarine dunes" or sand waves. Their profiles are likewise well known through the depth recorder, and their varied forms tell the physiographer that a generous supply of fine sand is here being moved about on the sea floor by tidal currents and shaped into large sand waves not unlike some of the great dunes of Imperial Valley or the Sahara.



From H. W. Murray

THE MENDOCINO ESCARPMENT
PROBABLY THE SEAWARD CONTINUATION OF THE GREAT SAN ANDREAS FAULT OF CALIFORNIA.



After Veatch and Smith

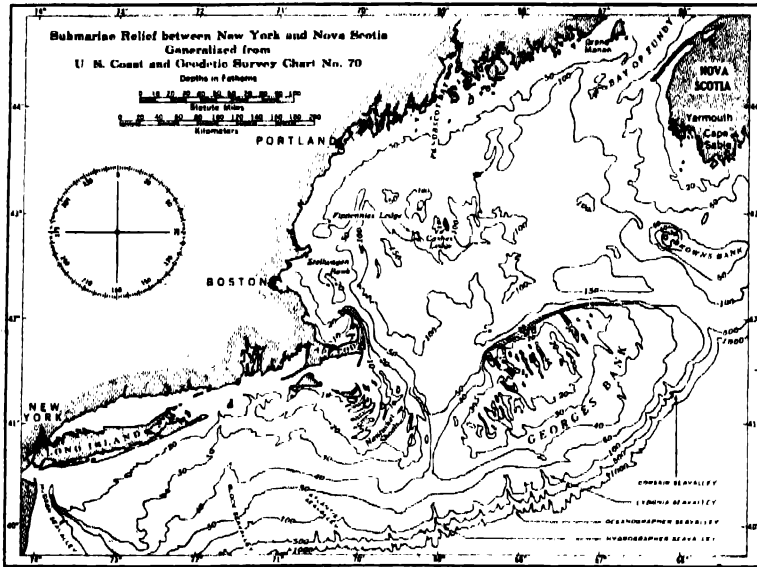
SUBMARINE RELIEF BETWEEN CHESAPEAKE BAY AND CAPE COD.

THE BROAD CONTINENTAL SHELF BETWEEN CHESAPEAKE BAY AND CAPE COD SHOWS THE REMAINS OF TERRACES, ESTUARIES AND CAPES FROM FORMER AND LOWER STANDS OF SEA-LEVEL. THE DEEP CANYONS OF THE CONTINENTAL SLOPE ARE IMPORTANT FACTS IN EARTH HISTORY.

One of the largest observed is over 60 feet high and 1,000 feet horizontally between crest and trough. Similar conditions were found in the North Sea by the Netherlands hydrographers in 1935 along the coasts of the Low Countries where strong tidal currents and sandy bottoms are also found. Fortunately, a complete report of this excellent work has been published.

The Gulf of Maine is only partially surveyed, but the first season's results show, as is to be expected, that the bottom relief here is unique. In the basins or depressions between about 540 to 900 feet, the depth recorder profiles reveal

that a layer, sometimes several layers, of silt cover the sea bottom. In some places the silt is as much as 60 feet thick. The automatic depth recorder shows this plainly. Whenever the difference in radiation resistance of the layers of water becomes great enough, as happens in the case of the silt-laden bottom layers, an echo is received from the boundary between the layers. The same principle is used in seismic prospecting to determine the thickness of sediments thousands of feet down in the earth. In echo sounding, however, relatively little energy from an electrical oscillator is used to create the impulse causing



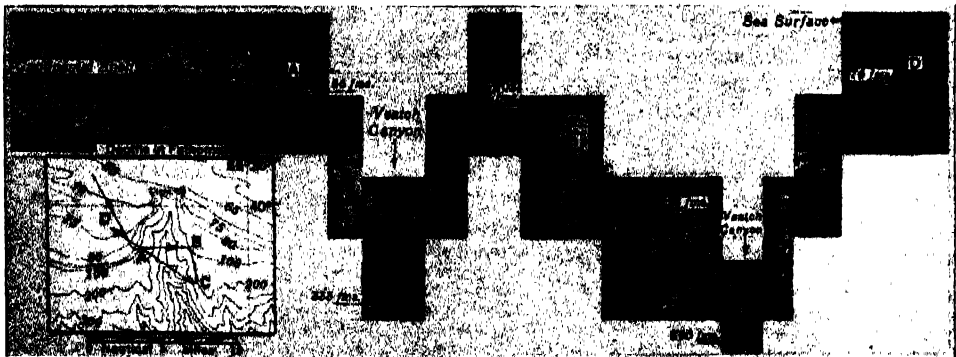
THE VARIED SUBMERGED LAND FORMS

OF THE GULF OF MAINE AND GEORGES BANK ARE IMPORTANT CLUES TO EARTH HISTORY. SELECTED CONTOURS INDICATE THE MAJOR FEATURES ONLY. SURVEYS OF THE REGION ARE INCOMPLETE.

echoes; whereas in seismic reflections a considerable charge of explosive may be necessary.

Most of the bottom of the Gulf of Maine is irregular and broken as compared to the continental shelves along other coasts at approximately the same depths. The Gulf is practically a medi-

terranean sea because the eastward extension of the Coastal Plain cuesta forms a great submerged tongue known as Georges Bank, and this bank acts as a barrier to the waters deeper than about 270 feet. Except for the two channels between Georges Bank and Nova Scotia the Gulf may be considered as a closed

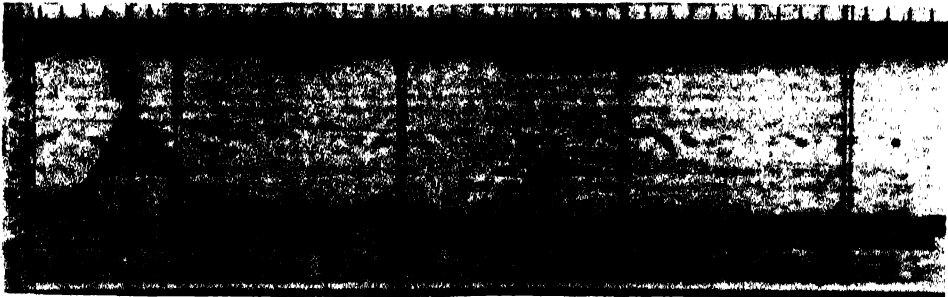


ACTUAL ECHO SOUNDING RECORD ACROSS HEAD OF VEATCH SEAVALLEY 95 MILES SOUTH OF NANTUCKET ISLAND, SHOWING FLAT CONTINENTAL SHELF AT LEFT AND AT RIGHT THE V-SHAPED PROFILE CHARACTERISTIC OF CONTINENTAL SLOPE CANYONS. A, B, C, D ON INSERT AND PROFILE SHOW ROUTE OF SHIP CROSSING AXIS OF VEATCH CANYON TWICE. THE VERTICAL EXAGGERATION OF SCALE IS 13 TO 1.

body of water to waters deeper than 45 fathoms. It is therefore understandable why here thick layers of silt are collecting in the basins which are not exposed to the force of the tidal currents sweeping over the banks and the continental shelves.

Two notable observations might be mentioned. Fippennies Ledge is almost as flat as a table at a depth of about 228 feet, while Cashes Ledge, 20 odd miles east, rises in rocky irregular form to within 30 feet of the surface without any prominent trace of the stand of the sea that may have been responsible for the

found here. Surveys of this area are also only partially complete, but a few of the depth recorder profiles made during surveys of the coast of South Carolina show some unusual forms, and the survey has progressed far enough to indicate that the flat part of the shelf does not break so abruptly to the stream-eroded type common to the continental slope north of Cape Hatteras. The change is more gradual and the slope itself more gentle. Near the seaward edge of the shelf several distinct depressions several miles in diameter and 200 feet deep have been found. One of them is



U. S. Coast and Geodetic Survey, 1940

ECHO SOUNDING RECORD OF SECTION OF THE GULF OF MAINE.
SILT COVERS LARGE AREAS OF THE GULF AS SHOWN BY THE SMOOTHER UPPER TRACE THROUGH WHICH THE BOTTOM IRREGULARITIES SOMETIMES PROJECT. VERTICAL EXAGGERATION ABOUT 13 TO 1.

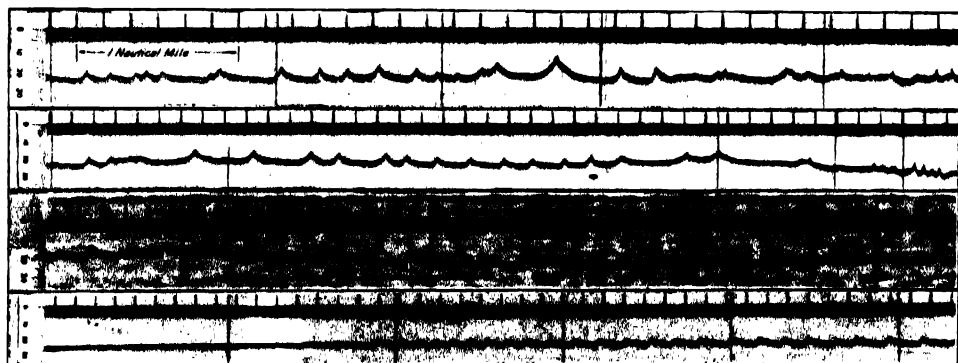
wave-cut top of Fippennies Ledge. It would be unwise to draw positive conclusions on the history of this region until the entire Gulf has been well surveyed; but because the great Glacial ice caps probably advanced over the Gulf as far as Georges Bank, the area is undoubtedly one of the most significant and fruitful regions in the world to the student of geomorphology.

One other region which will be embraced by the new surveys and which possesses to some degree a character of its own is the shelf and slope off southeastern United States. In this area the Gulf Stream bends close in shore and the continual flow of this vast and powerful current has doubtless been largely responsible for some of the conditions

at a depth of about 750 feet. A number of small plateaus or mesa-like features were revealed, and in one instance a distinct but small fault scarp was noted in depths of about 180 feet.

From the few examples briefly described, I think one may draw a few conclusions, most of which have been stated in part by a number of writers in this field during the past century, among whom are Dana, Hull, Spencer, Lindenkohl, Davidson, Shepard and Veatch.

Summarizing briefly, it is obvious that submarine relief, from mountains to valleys, is quite like the landforms we see on the land above the sea. The most striking change in characteristics of submarine relief occurs at the edge of the continental shelves. The continental



U. S. Coast and Geodetic Survey records, 1939

DEPTH RECORDER PROFILES OF SAND WAVES ON NANTUCKET SHOALS.

STRONG TIDAL CURRENTS WORK THE SAND INTO "WAVES" IN FORM SIMILAR TO SAND DUNES OF DESERT AREAS. SCALE AT LEFT SHOWS DEPTH IN FATHOMS. LARGEST SAND WAVE (SHOWN IN THE TOP RECORD) IS 60 FEET FROM TROUGH TO CREST.

slopes in many places throughout the world carry the unmistakable imprint of stream erosion; and we know the deep, characteristic V-shaped valleys are commonly formed by rivers flowing on land above the sea. The flat continental shelves, of such remarkable uniformity in depth all over the world, are due to the wave and current planation resulting from a slowly shifting sea-level between the limits of the present shelf depth. The general characteristics of some of the submarine mountains appear to be those of weathered mountains—not marine depositional forms. The submarine river erosion patterns found on many of the continental slopes are so definitely connected with many major river valleys on land, and the submarine counterparts of such streams are usually so youthful in physiographic character compared to their adjacent land valleys, that one may say it further confirms the idea that the continental slopes have at some time been exposed to subaerial erosion by the seaward continuation of many of the major rivers now flowing into the sea. The continents are, of course, more maturely eroded than the submarine continental slopes due to longer exposure of the former to sub-

aerial processes than the submerged slopes which have been truncated by the sea at the present shelf depths. The geologic age or ages of the drowning of the slope relief is not yet certain, but present evidence is strongly in favor of Pleistocene or Ice Age time. One significant point aiding the more exact dating of the canyons is the fact that the Hudson and Mississippi Seavalleys are cut much farther into the continental shelf than any others on the Atlantic and Gulf Coasts of the United States. It is rather well established that both these streams received during the recession of Wisconsin ice, some tens of thousands of years ago, considerably more water than they at present discharge into the sea; the Hudson through the Mohawk Channel and the Mississippi through the St. Croix, Illinois, Wabash and Lake Agassiz drainage. The cause of such great changes between land and sea is even more obscure and it is likely to remain so for some years to come.

I think, however, the future course is clear. If the existing mass of physiographic evidence is not satisfying proof of the first of these ideas, namely, that the continental slopes were actually exposed by a withdrawal of the sea to the

extent indicated (at least 10,000 feet), conclusive evidence will most likely be found when thorough surveys of the Mediterranean Sea, the Red Sea, Sulu Sea and other similar basins are completed. The second—when did such an event occur?—may be approached most profitably by extension of geophysical and geological exploration of the submerged continental borders, that is, by the collecting of core samples and careful geologic analyses, and submarine seismic exploration in such work as has

recently been done in this country under the sponsorship of the Geological Society of America and the National Research Council, and in England through the Royal Society and the International Geodetic and Geophysical Union.

In the meantime it seems important to scrutinize more carefully the fundamental facts supporting certain geological and biological ideas which do not harmonize with the story told so plainly by the forms of the lands beneath the sea.

EFFECTS OF THE WAR ON BRITISH EDUCATION

THESE changes which are to come in the secondary education system will require changes in the university system itself. It will require changes in method of accoutrement, and it will require some changes in the preliminary work inside of the universities. So, although I can not say how or in what way the solution will be found, I can, in the terms of the declaration of the President of the Board of Education, give you a picture of the way in which our minds are working. We are determined that we shall have a more flexible educational system, a system that is fitted to the educational requirements of the whole child population of the country, and not to any minority judged by any social or any ability standards. We shall have to reconstruct and reorganize our university groups. We shall have to reabsorb student populations with very unusual experiences. We shall have to absorb the whole academic population. But I am confident that when the total effects are seen, perhaps the most important of all the effects of the war on the educational life of the country will be those that Dean Holmes referred to—the effects of the war itself on the population of my country.

Reading the papers, you would come to regard England as an interesting interconnection of rubbish heaps, the results of air raids. It is true there are many such rubbish heaps, there are many scars, there are many wounds, but what strikes you most about life in England is its normalcy, its continuity, its sanity and its stability. People are looking things extremely

squarely in the face. They are recapturing lost values. They are finding that to be true to your standards of your job, whatever sort it may be, is the only thing that really matters, that carries you through in your time of crisis. Mothers of families, air raid workers, women called to munitions work to which they are entirely unaccustomed, young men called to serve in a variety of different military, naval and air forces; and many numbers of people called into different kinds of public work, entirely untrained, dug out by the roots, often going in physical fear—all finding in their work the peace of mind, the capacity for action, the capacity for clear thinking and a resolute determination to face all problems that confront them squarely on their merits and not on the basis of any "ism." It is against that background that these educational changes . . . are being worked out.

The day is not too far distant before this type of quiet work of reconstruction, which I bid you to notice is already beginning, can come to fruition. I am sure that just as the people of England are demonstrating in their daily lives that a great tradition can be molded and built to meet the great requirements of the new and strange horror of war, so the great traditions of the English educational system which was inevitably in its origins a minority system is capable of being molded, its values unimpaired, its essential spirit kindled and broadened to meet the requirements of a whole new generation and a new and rekindled people.—*Noel F. Hall, Educational Record, July, 1941.*

DISTRIBUTION OF TORRENTIAL RAINFALLS IN THE UNITED STATES

By Dr. STEPHEN S. VISHER

PROFESSOR OF GEOGRAPHY, INDIANA UNIVERSITY

WHAT counts as to rainfall is the actual amount that falls and when it falls, not averages. Plants can not grow in response to "expected or probable" amounts. Places which receive the same annual amounts of rain may have quite different conditions for plant growth because of differences in the time of fall as to season and as to intensity.

Just as there are recognized in the United States three chief types of annual precipitation totals (humid, semi-arid and arid) and three types of seasonal totals (largely during the cooler season, chiefly during the warmer months, and "uniform"), so are there three types of rainfall, gentle or light, moderate and torrential. Drizzles are the extreme type of gentle rains, while "cloudbursts" which yield several inches of rain in an hour are the extreme type of torrential rains.

Although all parts of the United States receive some rainfall of each of these three types, there are noteworthy regional contrasts in their relative importance. Gentle rains are characteristic of the cyclonic Lows which bring most of the rainfall of the North and much of that of the cooler months in the South.

The northern half of the country has an annual average of more than twice as many light rains as the southern half, and the northeastern region more than three times as many as the Southwest. The greatest number in the East, about 100 per year, occur in New York and Pennsylvania. The fewest, less than 20 per year, occur in southeastern California and Arizona. Of moderate rains (.26 to 1.0 inches in a day), the eastern

fourth of the country has about 40 per year, nearly twice as many as the western half. An area centering in West Virginia has more than five times as many as the arid Southwest.¹

TORRENTIAL RAINS

Several types of rainfall are classed as torrential. First may be considered the regional contrast in rainfalls of one to two inches per day. The northeastern states have such rains an average of less than twice a year while the southeastern states have an average of more than six a year.¹

Of rainfalls in excess of two inches in a day, the extreme North and most of the West has less than one a year while the Gulf Coast has an average of more than four a year.¹

Of rainfalls of over one inch in an hour, the South has an average of more than three a year while the northern part of the North and all the western half of the country has less than one such rain a year. Much of the Gulf Coast has more than six such rains a year.¹

The maximum precipitation in one hour received at the leading Weather Bureau stations during a 20-year period was less than two inches in the western half of the country and in the northern part of the northeastern quarter, but was more than four inches near the Gulf Coast.¹

A large mass of data on torrential rainfall has been organized by the senior drainage engineer of the U. S. Bureau of

¹ J. B. Kincer, "Precipitation in the U. S." Atlas of American Agriculture, U. S. Department of Agriculture, Washington, 1922.

Agricultural Engineering.² The records analyzed are of the rainfalls which occurred in periods ranging from five minutes to 24 hours, during 30 years at the 208 U. S. Weather Bureau stations which possess recording rain gauges. Yarnell published tabulations of the data and presents his generalizations therefrom in more than 70 maps. Summaries of the regional contrasts are appropriate here.

The amount of rain which falls in the sharpest brief rains varies regionally in a systematic manner, the largest totals occurring along the Gulf Coast, the smallest occurring in the arid parts of the West; the northeastern part of the country is intermediate. Of the most common type mapped, the amount to be expected in five minutes in half of the years, the totals in the arid West are less than .15 inches, in the Northeast about twice that amount, and along the Gulf at least three times that amount, or more than half an inch. In each decade, some one five-minute rain yields about a quarter inch in the West, nearly half an inch in the Northeast, and about .65 inches near the Gulf. The maximum rainfalls in five minutes reported are 1.9 inches at Taylor, Tex.; 1.2 at Augusta, Ga.; and 1.0 at Terre Haute, Ind., Harrisburg, Pa., and Portland, Me.

Rains yield ten-minute totals of somewhat more than an inch along the Gulf once a decade but less than a half inch in the western fourth of the country; in the Northeast, the totals are about intermediate. The maximum rainfalls in ten minutes reported are 1.9 inches at Taylor, Tex., 1.7 at Tampa, Fla., 1.4 at Valentine, Neb., Portland, Me., and Northfield, Vt.

An inch of rain falls in fifteen minutes once a decade at the Northeast, less than half that amount in the far West, and

about 1.5 inches near the Gulf. The maximum rainfalls in fifteen minutes reported by Yarnell are 2.3 inches at Pensacola, Fla., and Taylor, Tex., 2.1 at Augusta, Ga., and 2.0 at Houston, Tex., and Tampa, Fla. A rainfall of three inches in 15 minutes is officially reported, however, from Holland, S. C. (8/28/96), and one of 3.9 inches from Galveston, Tex. (6/14/71).

Rainfalls of more than two inches in a half hour occur each decade in the Southeast, but the half hour totals to be expected each decade are less than half an inch in part of the Northwest and 1.25 inches in the Northeast. The maximum rainfalls in a half hour reported by Yarnell are 3.6 inches at Pensacola, Fla., 3.1 at Kansas City, Mo., 3.0 at Anniston, Ala., Hatteras, N. C., and Thomasville, Ga., 2.9 at Brownsville, Houston and Taylor, Tex., and Tonapah, Nev. Higher records reported in the *Monthly Weather Review* are 9.2 inches at Guinea, Va. (8/24/06), 8.0 inches at Taylor, Tex. (9/9/21) and 4.1 at Biscayne, Fla. (3/28/74).³

In an hour, the Gulf Coast receives each decade a downpour of about three inches, the northern part of the East one rain of about half that total, and the West one of one third that total. The maximum rainfalls in an hour reported by Yarnell are 5.3 inches at Galveston, Tex., and Hatteras, N. C., 4.7 at Brownsville, Tex., and Kansas City, and 4.3 at Key West, Fla. Higher official records reported elsewhere include, in addition to those reported under 30 minutes, 5.8 inches at Oakdale, Neb. (7/16/20), 6.9 at Tridelpia, W. Va. (7/19/88) and 8.0 at Ft. Mojave, Ariz. (8/28/98).

The regional contrasts in the totals of rain to be expected in periods with a length of five to sixty minutes are, therefore, similar. For each type, the Gulf

² D. L. Yarnell, "Rainfall Intensity-Frequency Data." Miscel. Publ. No. 204, U. S. Department of Agriculture, Washington, 1935.

³ Some of these extra records were assembled by J. R. Theaman in a booklet "Heavy Rainfall Records," Indianapolis, 1931.

Coast receives totals of about three times as great as the Far West and approximately twice as great as the Northeast.

The regional disparity in the totals of rainfall received in short periods increase with the length of the period. For example, 2-hour rains yield three inches of rain every other year along the Gulf Coast, but such rains happen less than twice a century near the Canadian border, or in the western third of the country. The totals received once in two years are for the Northeast about an inch, and for the Northwest less than a half inch. Two-hour rainfalls in excess of four inches are reported from 43 of the 203 widely scattered American stations, distributed as follows: in the Northeast (21 states) five, in the West one, in the Upper South (Oklahoma to Maryland) eleven, and in the Deep or Lower South (the Gulf States, Georgia and South Carolina), 26. The maximum falls at those stations in those thirty years were 7.5 and 7.1 inches in Texas and Florida. Several greater totals have been officially reported from other stations, for example, 11.5 inches at Campo, Calif. (8/12/91), 8.0 inches at Ft. Mojave, Ariz. (8/28/98), Tama, Ia. (8/2/29) and Taylor, Tex. (9/9/91).

Four consecutive hours of hard rain occur much more rarely in the North and West than in the South. During each average five years the Gulf Coast has at least one four-hour rain yielding more than four inches. Such a rain does not occur, Yarnell reports, oftener than about once a century in the Northeast. The maximum to be expected for this interval is about two inches at the northern border of the country and less than 1.5 inches in much of the West. Of eight-hour rains, the Gulf Coast normally has one each decade which yields six inches, while the North receives in a century a maximum rainfall of less than about five inches in eight hours, and the West a maximum of less than four

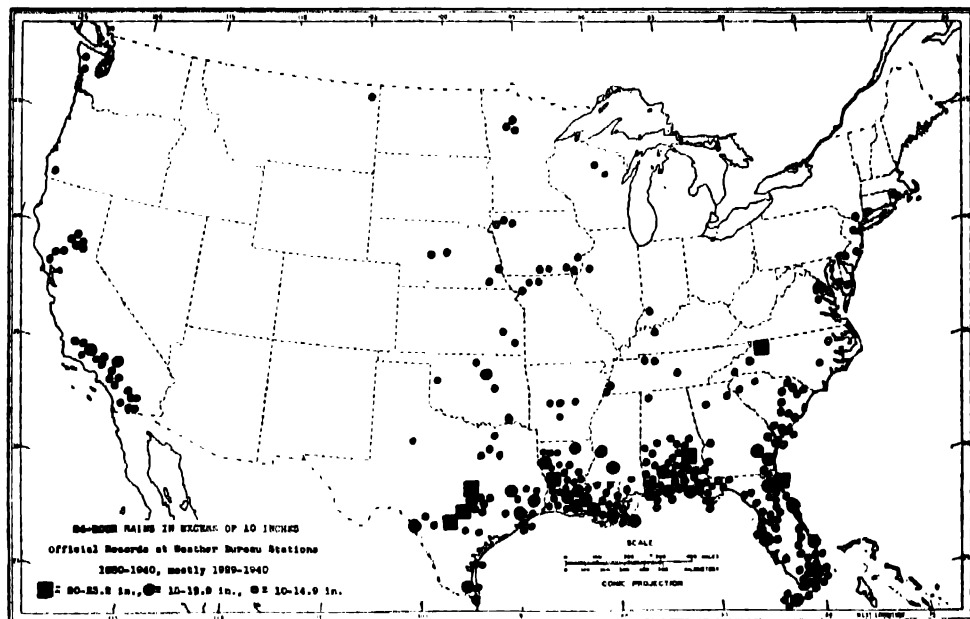
inches. During each average decade, the maximum eight-hour rain is less than 3.5 inches in the Northeast and less than 2.5 inches in the West.

The regional contrasts in sixteen-hour rains are of similar proportions: The Gulf Coast receives more than twice as much rain as the Northeast, and more than three times that of the West.

In some one 24-hour period, the Gulf Coast receives each average decade a rainfall of more than seven inches, or more than twice as much as is received in the Northeast, and more than three times as much as in the West. The totals for the heaviest 24-hour fall in a century display still greater contrasts, the Gulf Coast receiving about three times as much as the Northeast and more than four times as much as most of the West. A 24-hour rain of six inches is to be expected twice a decade near the Gulf but less than once a century in most of the Northeast. The greatest 24-hour rainfall of each average five years is less than three inches in much of the Northeast, and is less than two inches in much of the West.

A SPECIAL STUDY OF 24-HOUR RAINS IN EXCESS OF TEN INCHES

Evidence supplementary to the data just summarized has been sought in numerous sources. One highly suggestive new body of data deals with rainfalls of ten inches or more in 24 consecutive hours. A total of 293 American records of such rains have been culled from the official local records. The states having most such official records are Florida 68, Louisiana 44, Alabama 38, Texas 32, California 25, and South Carolina 15. The seven official records of more than 20 inches falling within 24 consecutive hours are as follows: 23.2 inches at New Smyrna, Fla., October 9-10, 1924; 23.1 inches at Taylor, Tex., 9/9-10/21; 22.2 inches, Altapass, N. C., 7/15-16/16; 21.4 inches, Alexandria,



DISTRIBUTION OF HEAVY RAINFALLS IN THE UNITED STATES

La., 6/14-16/86; 20.4 inches, Smithville, Tex., 6/29-30/40; 20.1 inches, Montell, Tex., 6/28/13; 20.0 inches, Elba, Ala., 3/15/29. Records of 18 or 19 inches in 24 hours are held by four other Weather Bureau stations in Louisiana, two in Texas, and one in Georgia.

Many of these rainfalls of more than ten inches in 24 hours fell in less than 24 hours. For example, Beaumont, Tex., got 13.5 inches in three hours (5/18/23) and Taylor, Tex., received 10.3 inches in three hours, and 23.1 inches in fifteen hours (9/9/21).

The location of the records are shown on the first accompanying map, where the amount of rain is indicated by the symbol used. The squares represent the records of twenty inches or more of rainfall in 24 hours, the large dots locate the rains of 15-19.9 inches, and the circles those of 10-14.9 inches. Because parts of some southern states have had numerous such rains, the lack of space prevents the precise locating of some of the circles. For example, the southern half of

Alabama has had 37 such rains, 13 of them in the small southwestern projection. Consequently some of the circles are placed in the Gulf. Other crowded areas are in southern and eastern Florida and in southeastern Texas.

This first map makes conspicuous the fact that the southern part of the South has had many rains in excess of ten inches in 24 hours, and that there is a rapid decline in numbers within a hundred miles or so of the coast not only along the Gulf but along the Atlantic and Pacific. In the interior, there is a progressive northward decline in the number of these very hard rains except for local increases in the Southern Appalachians and near the Balcones Escarpment of the Texas Plateau.

The following analysis of the storms which brought rainfalls in excess of ten inches in 24 hours is of interest. Of 202 storms which brought such rains to one or more Weather Bureau stations, 162 occurred in the South, 24 in the North, 16 in the West. Of the 39 storms which

yielded more than 15 inches in 24 hours, the South had 37, California two. As to season, the summer had 82 rains of over ten inches in 24 hours, autumn 75, spring 29, and winter 16. As to month, September had 47, July 33, August 27, June 22, October 18, March 13, November ten, April and May each eight; the three winter months each about four. Of 16 such winter rains, the South had seven, California eight, Washington one. Of 29 ten-inch spring rains, the South had 23, California five, and Missouri one. Of 82 summer rains of this amount, the South had 62, the North 19, Montana one. Of the 75 autumn rains the South had 67, the North seven, California one. Thus of the North's rains in excess of ten inches in 24 hours four fifths occurred in summer, in contrast to about one third in the South.

FREQUENCY OF TEN-INCH RAINS

The sharp regional contrast in the number of exceptionally heavy rains indicated by this map is made even more clear by an analysis. The map shows all the records, some of them established sixty years ago, when Weather Bureau stations were less uniformly distributed and conducted than at present. The analysis now to be presented concerns the records during a recent ten-year period (1929-1937 and 1939).

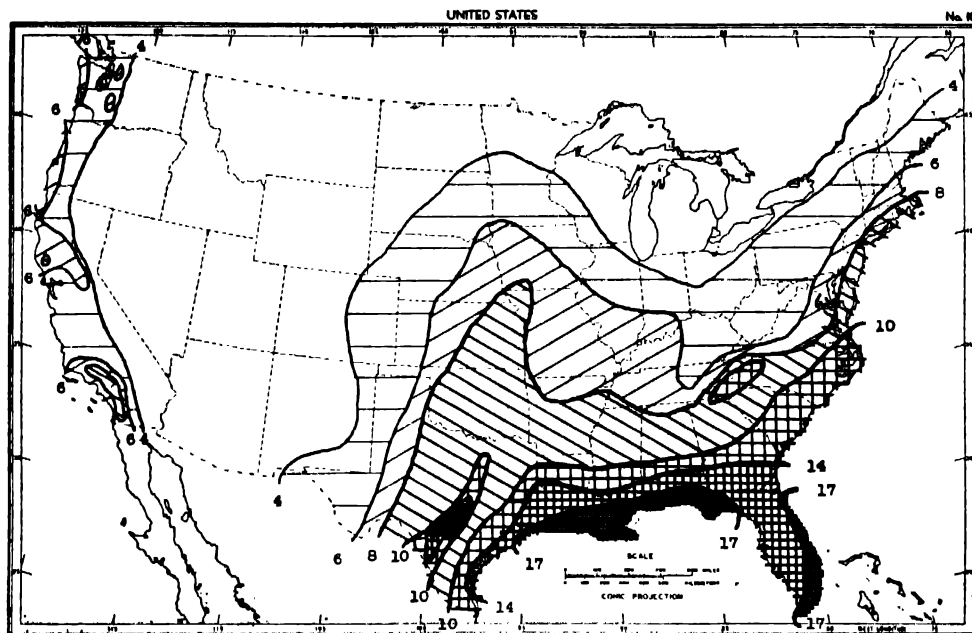
During that recent decade, the Deep South, that is, the five states bordering the Gulf plus Georgia and South Carolina, had eight official records of rains of more than fifteen inches in 24 hours. The "Upper South" (from Oklahoma to Maryland) had one such rain in that period, but the West and North had none.

The Deep South had 47 official records of rains of 10 to 14.9 inches in 24 hours in the decade. The Upper South had eight, the North four, two each in Missouri and New Jersey. The West had one.

In proportion to area, the Deep South with 55 had about ten times as many records of rains of over ten inches in 24 hours in the decade as did the Upper South, and more than a hundred times as many as did the northeastern 21 states. No such rain was recorded from the Rocky Mountain States during that ten-year period and only one from the Pacific States.

The second map herewith shows the amounts of rainfall which may reasonably be expected in the 24 hours of heaviest rainfall of a fifty-year period. It serves as a sort of summary of the foregoing data on the distribution of great rainfalls and their frequency.

Thus it is apparent that these data supplement other evidence in indicating that there are systematic regional contrasts in the United States in torrential rainfalls. In brief, the United States may be divided into four great regions with respect to the amounts of rainfall records in short periods. These regions are: The Deep South (the Gulf States plus Georgia and South Carolina), the Northeast, the West, and a zone between the Deep South and the Northeast consisting chiefly of the Upper South (Oklahoma to Maryland). The Deep South receives an average of more than three times as much rainfall in short periods of exceptionally hard rain as does the West, about twice as much as the Northeast and about one and a half times as much as the transition belt of the Upper South. It not only receives much larger maximum falls in such hard rains but receives very hard rains much more frequently than does the North and West. For example, three inches of rain falls within two consecutive hours once in two or three years or oftener, on the average, close to the Gulf, once in two to five years in most of the Deep South, once a decade in the Upper South, once a half century in the southern part of the North, but only about once a century, Yarnell re-



AVERAGE MAXIMUM 24-HOUR RAINFALLS
INCHES TO BE EXPECTED IN THE HEAVIEST RAIN OF 50 YEARS.

ports, along the Canadian border and in the West. In other words, such rains are about fifty times as common at the southern border of the eastern half of the United States as at the northern border. The regional contrast is even larger for rainfalls of greater amounts: rainfalls of five inches in eight consecutive hours are unknown in most of the North, but near the Gulf occur twice an average decade.

REASONS FOR THE REGIONAL CONTRAST IN TORRENTIAL RAINFALLS

Just as there are meteorological reasons for the contrasts in annual and seasonal totals of rainfall, so are there reasons for the regional contrasts in torrential rainfall. Three influences cooperate to produce most of the differences. These are (1) variations in the availability of abundant atmospheric moisture; (2) variations in the intensity of convectional atmospheric disturbances, the great cause of thunder-

storms; and (3) variations in the intensity of cyclonic storms. The most important cyclonic storm in the production of exceptionally heavy rains is the tropical cyclone which is called a hurricane if it is accompanied by violent winds, but which frequently brings torrential rains even if its winds are moderate. A fourth factor of local influence in causing the regional contrasts in the number and size of the torrential rains are differences in topography. Upon the windward side of the Southern Appalachians and Pacific Coast Ranges there are occasional hard rains of the so-called orographic type.

The availability of atmospheric moisture varies with the accessibility to sources of moisture, chief of which is the ocean. Hence the air over areas remote from the sea usually contains less moisture than that over coastal areas and, having less, it can yield less rainfall when cooled sufficiently to cause precipitation. Important in this connection is

the fact that there is much more active evaporation from warm bodies of water such as the Gulf of Mexico than from cool ones, such as the Great Lakes. As warm air can include much more moisture than can cool air, it can give up more when sufficiently cooled. Moreover, in warm regions such as the Gulf States, the air often is warm to a much greater height than is usually true in the North. These several conditions powerfully influence the distribution of torrential rains, causing a northward and interior decline. The less rapid northward decline in the Mississippi Valley than between there and the eastern mountains is partly due to their greater accessibility to the Gulf of Mexico, the great source of moisture for most of the eastern half of the United States.

Thunderstorms, the immediate cause of most of the sharp torrential rains, are more than twice as numerous in the South as in the North; the Gulf Coast east of the Mississippi has more than three times as many as the Canadian border.⁴ In the West, thunderstorms are less common than in the Northeast, and the number which yield much rain to lowlands is still smaller.

Tropical cyclones, the cause of many of the greater rains, are relatively numerous along the Gulf and South Atlantic coasts. An average of about 20 cyclonic disturbances impinge upon the Gulf of South Atlantic coast each year.⁵ Only a few are hurricanes, but some of the heaviest rains have come from slow-moving tropical cyclones which do not have strong winds. Tropical cyclones commonly lose much of their intensity, or even die away, shortly after leaving the sea. This latter fact is an important

cause of the abrupt decrease inland in the number of rains in excess of ten inches in 24 hours.

SOME RESULTS OF THE TORRENTIAL RAINS

Torrential rains necessarily result in much runoff and flooding, and the larger rains usually do considerable damage. For example, the rain of 8 to 20 inches in 24 hours on June 29-30, 1940, in southeastern Texas was estimated by the local Weather Bureau official to have caused immediate damage exceeding \$700,000, of which \$455,000 was to crops, \$85,000 to live stock, and \$200,000 to buildings, roads and bridges, etc. Seven people were drowned. Even greater was the damage caused by the exceptional rain of March 14-15, 1929, in southeastern Alabama when 8 Weather Bureau Stations recorded from 10 to 20 inches of rain in 24 hours. Several towns were badly flooded, the water standing 10 feet deep in parts of Elba. The damage was officially estimated to have been more than \$3,750,000, not including suspension of business.

Less spectacular than flooded towns, valleys and fields, but much more serious in the aggregate is the damage to the soil by exceptionally heavy rains. The sloping land of the South has suffered such extensive erosion that already more than 40 million acres which were formerly farmed have been abandoned because much of the topsoil is gone or numerous deep gullies have been formed. Soil erosion is especially serious in the South not alone because the chief crops grown there (cotton, corn, tobacco, peanuts, vegetables) are row-cultivated or inter-tilled and hence afford little protection to the soil, but also because torrential rains are exceptionally numerous and intense there. Thus the distribution of torrential rainfalls in the United States helps to explain the relative amounts of soil erosion and of poverty.

⁴ W. H. Alexander, *Monthly Weather Review*, 63: 157-158, 1935.

⁵ S. S. Visher, *Monthly Weather Review*, 58: 62-64, 1930. *Idem*: *Geographical Rev.*, 15: 106-114, 1925. I. M. Cline, "Tropical Cyclones," New York, 1926. I. R. Tannehill, "Hurricanes," Princeton, N. J., 1938.

SYNTHETIC CONCEPTIONS IN NEURO-PSYCHOLOGY

By the late Dr. JOSHUA ROSETT

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A KNOWLEDGE of the cause of angular motion has enabled the scientist to align under a common heading such widely different phenomena as the spiral form of the pine cone, the eddy in the water of the washbowl when the outlet is opened, the rotations and revolutions of the heavenly bodies, the form of the "twister" and perhaps the recurrence of social epochs. While the physical sciences have made great progress in the building up of such synthetic conceptions, the science of biology is lagging far behind, and this is especially true in the field of medicine. I shall attempt to show that such apparently widely different phenomena as the epileptic seizure, the onset and the awakening from sleep, the reaction of being startled, states of anxiety which merge into a number of the neuroses, the states of attention, of thought, of imagery and of hallucination, exhibit, upon analysis, not only a remarkable sameness of the elements of which they are constituted but a striking sameness of the pattern into which these elements are arranged as well.

In the same manner that the solution of a mathematical equation is made easier when reduced by the elimination of the common factors, so must an understanding of the manner in which the above-mentioned conditions differ from one another be enhanced by the mental abstraction of the features common to all of them.

An analysis of the physiological and psychological states enumerated discloses the fact that each of them begins with a period of disorientation of some degree in the present and proximate surround-

ings; that this period is followed by one of mental activity of one kind or another; that the latter is, in its turn, succeeded by more or less profound unconsciousness and by muscular activity, which merges into muscular relaxation; and that the cycle of each of these conditions is completed by a recurrence of the same events in the reverse order of succession of their onset. But though the order of the events is constant, we shall find that in a large number of instances the cycle is abbreviated, being short of its later stages and, in at least one instance, of the first stage. Whatever be the shortages, however, the student will have no difficulty in discovering the basic identity of the incomplete with the complete pattern.

Mention has been made of the fact that all the psychological and physiological conditions enumerated begin with a period of disorientation in the present and proximate surroundings. Before proceeding with our analysis we must pause for a brief definition of the latter terms.

In the first place the terms "present" and "proximate," as here employed, have reference to that part of the external and internal environment which is at the moment directly accessible to the sensory receptors. Standing by itself, however, such a definition is entirely inadequate from the point of view of a study in which the factor of *awareness* or *consciousness* is a prominent feature. For although it is true that the presence of a radio set is capable of producing a disturbance of the sensory receptors in a young baby, an idiot, a savage or a dog,

yet the disturbance is not informative to them of its particular significance, namely, that of the presence of an instrument for the conversion of certain electrical waves into sound. Such significance of a particular disturbance of the sensory organs is brought about by the memory of a great variety of past experiences with the particular object or condition.

To be disoriented in the present and proximate surroundings implies, therefore, a break at any point in the course of the sensory receptive apparatus by which it is disabled from conveying the disturbance of the sensory receptors to the associative apparatus of the cerebral cortex. The latter, being the "seat" of memories of past experiences, the result of an inability of the sensory receptive apparatus to convey to it different disturbances of the sensory receptors is that the specific significance of the present and proximate objects and conditions is lost, and the person or the animal is therefore practically severed from the immediate surroundings.

Since from the point of view of the present analysis the term "proximate" is applied to that part of the environment which is directly accessible to the sensory receptors, it must be distinguished from its synonym "nearby." A star is far away, yet since it can produce on the retina a direct impression which is capable of reviving memories of its significance, it is, from this point of view, proximate. On the other hand, microorganisms, of whose presence on the skin the person is unaware are, from the same point of view, "distant."

By the same token, the awareness of the presence of an object which is not at the moment productive of a perceived disturbance of the sensory receptors, implies orientation in the distant and the past—implies an act of memory of experiences with that object or condition at some time in the past—irrespective of whether that object is situated nearby

or far away. Such awareness, which is independent of the activity of the sensory receptive apparatus is a purely mental act. Thus, a person may be aware of the presence of stars far away, or of microorganisms nearby, neither of which affects his sensory receptors at the time.

With these definitions in mind we may proceed with the analysis of the patterns of the several types of behavior in question.

THE EPILEPTIC SEIZURE

A number of different forms of this disorder are known to physicians, but no matter what the form, with the single exception to be pointed out later, they all begin with a period during which the person is more or less disoriented in his proximate surroundings.

A number of epileptic seizures set in with such rapidity that neither the subject nor the outsider can observe their development. In those instances in which the attack develops gradually, especially when the first stage is of considerable length, the subject remembers his experiences during that stage of its progress and is able to give an account of them afterwards. Soon after the person has become to a greater or less extent confused, or unconscious, of his proximate surroundings, distorted memories of certain past experiences, acquired directly or by representation, in a number of cases become active in the form of hallucinations. The degree of vividness of this distorted orientation in the past is in direct proportion to the degree of disorientation in the present. The reason for the latter will be pointed out later. When, for example, a person, during the onset of the seizure, has a vivid vision of a knight in armor on a fiery steed, who speaks in a thunder-voice, it is a certainty that he is at the time quite unconscious of his present and proximate surroundings. When the "vision," on the other hand, is hazy, orientation in the present is not entirely

extinct. In one of my cases the subject, a young woman, had one of her "minor" attacks as she was about to board a street car. The hallucination, which was the same in every recurrent seizure, was that of a balcony or veranda on which a number of well-dressed people were having tea. The "vision" was enveloped in a bright haze. While she was experiencing this hallucination, she was to some extent aware of the fact that the car conductor was urging her to board the car, and her feelings were those of uneasiness and embarrassment.

Following the stages of disorientation in the proximate surroundings and the mental activity of hallucination, the "major" epileptic becomes totally unconscious. The succeeding stages of the seizure are characterized by muscular rigidity and convulsions, and these are followed by a degree of muscular flaccidity which is in direct proportion to the degree of the preceding muscular activity.

After a variable period of unconsciousness, recovery takes place. The recovery of muscular function is manifested by a return of tonus, which may be detected by palpation and by different movements of the body and the limbs. A mild convulsion is not infrequent at this stage. Mental activity is next manifested by the occurrence of dreams, which are very common upon emergence from the major seizure. Orientation in the proximate surroundings is the last to return. In the process of taking rapid moving pictures of a number of such seizures, an arc light was placed near the patient. Upon awakening, a number of these patients gazed confusedly at the bright light and tried to reach out for it. They were dazed. When they were questioned, their answers were irrelevant in content, and the sentences were badly formed, with omissions and substitutions of wrong words.

This is the cycle of events of the complete, or major, epileptic seizure. The

minor seizure is simply one in which the disability falls short of some of the last stages of the major seizure, rarely reaching the point of complete unconsciousness and still more rarely that of convulsions. The person is more or less disoriented for a variable length of time in his proximate surroundings, then recovers. Or the disability may proceed to the next stage of hallucination, at which point recovery may set in. In a number of other cases mental activity may be completely suspended for a few moments, and the person may quickly recover before having a convulsion, or after a very brief and localized muscular spasm. A patient who was under my observation for some years had had a number of minor seizures daily. The disability during each attack progressed to the stage of a momentary spasm of the muscles of mastication. The entire cycle of events occurred with great rapidity so that all that could be noted was the sound of the patient's teeth snapping together. He never fell, although he was somewhat dazed for a few minutes after each attack.

The several stages of the complete epileptic seizure are, therefore, the following: (1) disorientation in the present and proximate surroundings; (2) hallucinations, that is, a mental activity which consists in a vivid and distorted subjective reexperience of actual past experiences—a vivid and inaccurate orientation in the past and the distant; (3) complete unconsciousness; (4) muscular activity; (5) muscular flaccidity. These different stages are not, however, rigidly delimited but overlap on one another to a greater or less extent. Following the last, recovery takes place, in which the several stages enumerated recur in the reverse order.

There is one form of seizure which is short of the first stages—the so-called Jacksonian. The attack consists of a convulsive movement of a part or of a whole extremity, or of a part of the face.

Following the convulsive movement the muscles remain relaxed for a time. Throughout the attack the patient is quite oriented. When pointing out the reasons for the particular mode of succession of the several stages in the epileptic seizure, in the "startling" reaction, in the state of attention, of a thought, and the others, it will appear that the Jacksonian seizure is corroborative of the general argument held forth.

THE REACTION OF "STARTLING"

The condition for the production of this reaction is a sudden unexpected application of a stimulus, which need not necessarily be strong. The slamming of a door, a friendly slap on the shoulder from behind, a flash of lightning, the sight of a repugnant animal, the prick of a pin—almost any stimulus suddenly and unexpectedly applied causes the susceptible person or animal to bound into a state of more or less general muscular rigidity, in which the joints are immobilized by the equal contraction of the antagonistic muscles. Wild animals are "scared stiff" or "hypnotized" by the glare of a bright light at night and, becoming immobile, may be easily taken under these circumstances. It is for this reason that hunting at night by jack-light is prohibited in most of the states as being unsportsmanlike.

That much is familiar. A closer observation of this phenomenon reveals a number of interesting facts. It appears that the reason for the reaction is to be found in the fact that the nature of the stimulus not having been yet evaluated, the person or the animal can not react to it in an appropriate manner. Immediately the stimulus is evaluated, as when the person has had time to realize that the slap on the shoulder is by a friend, the general rigidity of the startle disappears. As the reaction consists in a fixation of the joints, we may legitimately surmise that it is a natural protective

measure, which, by the establishment of a fixed base, prepares the organism for any possibly needed movement of the body and the limbs for purposes of aggression or escape.

Rapidly as the muscular rigidity sets in after the application of the unexpected stimulus, however, it is preceded by certain sensory occurrences. What happens immediately after the application of the stimulus is that consciousness is suddenly and intensely focused on it—narrowed—so that the person or the animal becomes to a corresponding extent disoriented in the rest of the surroundings; and so small may become the residuum of consciousness, that it is in a number of instances completely suspended. The reason for the complete extinction of consciousness when it is reduced below a certain scope, will be more conveniently pointed out under the heading of "The State of Attention." The extent to which consciousness is reduced in the "startle" is attested by the frequency of irrational behavior of the surprised or frightened person who, when asked later the reason for such behavior, offers the familiar reply, "I was so surprised I didn't know what I was doing." For one not to know what he is doing implies a considerable reduction of his conscious state.

The sensory disability in connection with the reaction in question may also be judged by many familiar instances of a remarkable degree of different anaesthetics. I have elsewhere cited my own experience of a temporary disappearance of a violent toothache upon hearing the cry of "fire" on a floor below. I recently saw a woman with a number of burns on her body and limbs, which she sustained in the attempt to stamp out a spreading grass fire near her house. So startled was she by the threatened danger that she felt not the least pain from the burns at the time. The explorer Livingstone is said to have felt no pain when his arm was chewed by a lion.

In instances in which the cycle of mental and muscular events which constitute the reaction in question is drawn out in point of time, vivid imagery and hallucination are not uncommon. The content of such imagery and hallucination depends, of course, on the particular mental composition of the subject. The familiar stories of lonely houses haunted by ghosts and devils have their source largely in such imagery and hallucination of persons who could not evaluate the nature of certain stimuli to which they were exposed, and who reacted to the slamming of doors, the rattling of windows and the howling of the wind in the chimneys by a drawnout "startle."

Following a brief but intense "startle," trembling, automatisms and other involuntary abnormal movements are not uncommon. Muscular exhaustion manifested by flaccidity, which is popularly known as a "let-down" terminates the ordinary attack.

STATES OF CHRONIC ANXIETY

Persons oppressed by anxiety, or fear, or afflicted with grief or tormented by suspense for a considerable length of time, exhibit the essential manifestations of continually recurring drawn-out "startling" reactions. The latter are, however, very much obscured by certain activities of the autonomic nervous system. These tend to aggravate the entire condition to a point where the original causative stimulus is frequently lost sight of, so that the only proof of its causality is a cessation of its action, when, unless permanent damage to the tissues of the body has been done, the abnormal state is rapidly dissipated. In the description of the symptoms of the reaction of "startling" I have omitted to mention the manifestation of the activity of the autonomic nervous system—pallor, flushing, sweating, goose-flesh, irregular heart-beat, the arrest of digestion and others—for the reason that the common "startle"

is very brief, and whatever activity of the autonomic system is associated with it abates rapidly when the reaction is over. Under the continuous incidence of a stimulus to which the person can not react, however, the symptoms of activity of the autonomic nervous system in the long drawn-out and continually repeated reaction of "startling," constitute a source of chronic discomfort to the subject and a serious problem for the physician.

Through the obscuring haze of the symptoms of autonomic activity, it may be discerned that the subject is chronically somewhat disoriented in his surroundings, from which he is, consequently, to a certain extent severed. In popular language, "he lives within himself." This defective orientation in the present and proximate surroundings, not being sufficiently adequate to guide his memories of past experiences along channels of actuality, results in a kind of orientation in the past and the distant which, for the defect in the relations of the separate memories, is akin to dreaming or having hallucinations. The sudden stiffening of the muscles which characterizes the acute reaction of being startled has its equivalent in the state of anxiety in chronic muscular tensions alternating with periods of "let-down" or exhaustion.

THE ONSET OF SLEEP

The general resemblance of the onset of sleep to the epileptic seizure was noted many years ago by Dr. Gowers. A closer study of this condition reveals that the different steps, or stages, into which either of these states is divisible are the same, and that they follow each other in both conditions in the same sequence.

The first stage of the onset of normal sleep is a diminution of the activity of nervous apparatus which keeps the organisms "in touch" with the present and proximate surroundings—the sensory receptive apparatus. At a certain

point in the progress of this stage, while there is still a large residuum of orientation in the present and proximate surroundings, thought—that is, a correct orientation in the past and the distant—becomes active. With the further diminution of the activity of the sensory receptive apparatus, and the consequent diminution of the residuum of orientation in the present and proximate surroundings, memories (orientation in the past and the distant) cease to that extent to correspond to reality, and thought first merges into imagery and the latter into hallucination. This stage of sleep is followed by more or less profound unconsciousness.

Coincident with the onset of unconsciousness muscular activity takes place, manifested in a number of cases by the familiar jerking or startling movements. In a large number of instances these movements are sufficiently sudden and powerful to waken the sleeper. The next stage of sleep is characterized by continued unconsciousness and muscular relaxation.

In the process of awakening from normal sleep, the same as in the recovery from the epileptic seizure, the several stages of the onset are repeated in the reverse order. Muscular activity returns first, the person crouches, turns, stretches, yawns. Brief dreams are common in this stage. The person then becomes more or less rapidly oriented in the present and proximate surroundings.

ATTENTION AND THOUGHT

Attention may be said to be the first stage of any one thought. Whether attention is on memories—on the past and the distant—or on the present and proximate, the appreciation of the significance of an object, or condition, or an element of memory attended to, involves a correlation of that item with memories of experiences with similar and dissimilar items. Although most of these facts are familiar, an example or two will serve to bring out

their relevancy to the subject in hand. Observe the manner in which a textile merchant examines a piece of cloth in order to ascertain its quality. He looks at it and rubs it between his thumb and forefinger for a while, then stops, closes his eyes for a time, then opens them again, looks at the cloth and again rubs it between his fingers; and he repeats this action until he is satisfied of the quality. Even more familiar examples of such alternating actions may be observed in the tasting of a certain food or in the smelling of a certain perfume for the purpose of ascertaining, respectively, the taste and the fragrance. The exposure of the sensory receptors to the stimulus-object is alternated with an effort of comparing the present single impression with numerous memories of similar and dissimilar impressions in the past.

If, while the buyer is examining the cloth, one salesman will sing praises of its quality, another will tug the buyer by the sleeve, and a third will execute antics for his entertainment, the merchant will find himself unable to determine the quality of the cloth. He will say he can not "concentrate" his attention.

We must examine the significance of this "concentration" of the attention. We have noted that after gazing at the cloth for a while, the merchant closes his eyes. The same is true of the person who smells the perfume in order to ascertain its fragrance, except that the latter may close his eyes to start with, or if he keeps them open he gazes into infinity, that is, he is not looking at anything in particular. The fact is that in order to devote a certain degree of attention to any one object, condition, or thought, all the rest must be to that extent excluded from consciousness. And what is true of this relation of a whole object to all other objects, is likewise true of a part of an object to a whole. A minute attention to a drawer in a desk involves at the same time a corresponding degree of inatten-

tion not only to the rest of the furniture in the room but to the desk as a whole as well. In order to "think out" a problem relating to the stars, one must forget for the time being his other affairs. To the extent that the latter obtrude themselves upon the attention one can not think clearly about the stars.

In brief, a condition for a given degree of orientation within a small sphere is a corresponding degree of disorientation outside that sphere; and the smaller is the sphere attended to, the clearer is the orientation within that sphere and the wider is the scope of disorientation outside of it. In this respect the act of attention is analagous to the focusing of light. A light focused to a small bright point involves a corresponding absence of light outside of it.

Attention, however, refers to living organisms, the activity of whose functions is limited within certain bounds; a function which is either overactive or underactive beyond certain limits, ceases altogether. And this is likewise true of the state of attention, which may be progressively concentrated within a smaller and still smaller sphere down to a certain limit beyond which it ceases altogether. In other words, as the scope of disorientation increases in proportion as the sphere of attention is reduced, it is a fact that beyond certain limits the former spreads over the entire field, that is, the person becomes unconscious. Sustained attention on a small object or on a narrow line of memories is, as a matter of fact, conducive to sleep. The popular hypnotics, which consist in counting mentally a row of sheep, or of "reading one's self to sleep" are based on this fact. An objection might be discovered in instances in which the contemplation of a small object, such for example as the discovery of a certain abnormal cell under the microscope by a pathologist, will make him wide awake and alert. The fact of the matter is, however, that in this case the sphere of attention, far from

being circumscribed within the narrow outlines of the cell, is very much expanded by the numerous memories revived by the picture under the microscope. Persistent gazing at the same cell by a person to whom it represents nothing more than a small circle or oval, would almost certainly result in his falling asleep.

The onset of sleep induced by a contraction of mental activities along a narrow channel is particularly favorable to imagery and vivid dreams. As the scope of orientation in the present and proximate surroundings is progressively diminished by limiting the activity of the sensory receptive apparatus, a distorted orientation in the past and the distant becomes correspondingly active. The content of the imagery and hallucination in such cases, too, depends, of course, on the mental composition of the subject. The ambitious tradesman may find his competitors in the poorhouse and himself on the golden throne of a merchant prince. The mystic may have revealed to him the heavenly light. History indeed records instances in which members of mystic fraternities have been regularly instructed into the means of inducing in themselves a state of being in which that light would reveal itself to them, as, for instance, by intent gazing at the navel for long periods of time at a stretch. The modern mystic gazes at an acorn or at the point of a needle. The professional hypnotist instructs his subject to gaze at the fingertip held before the eyes while assuming a mental attitude of entire obedience to commands.

A detailed discussion of the muscular activity connected with the state of attention and of thought, imagery and hallucination, would take us too far afield. It is sufficient to say that the postures and movements associated with the rapidly changing states of attention are to a certain extent characteristic of each such particular state, though largely

dependent upon the habits of the individual. When attention is on an external object, the sensory organs are moved in the direction of the object to be examined or the object is moved in the direction of the particular sensory organs. Once the most advantageous spatial relation between the object and the sensory organs is established, the joints are immobilized by the equal contraction of the antagonistic muscles and the posture thus established is maintained for the duration of that act. The final relaxation of the muscles signals the end of the particular state of attention. When attention is on a given line of thought, the sensory organs are as far as possible protected by appropriate movements and postures from the obstruction of external stimuli, so that disorientation in the present and proximate surroundings, to a degree suited to the particular mental activity, may facilitate orientation in the past and the distant. A single hint regarding the temporal relation of muscular activity to thought must suffice. It is that planned action follows, does not precede, thought.

It appears, therefore, that, like the epileptic seizure, each state of attention, no matter how brief and fleeting, is initiated by a disorientation in the present and proximate surroundings, which is then followed by the mental activity of thought, imagery and hallucination—by an increasingly vivid and increasingly inaccurate orientation in the past and the distant. This stage is followed by more or less profound unconsciousness. The movements and the sustained postures are then resolved.

As in the case of the epileptic seizure, however, states of attention are seldom complete, usually falling short of one or more of the later stages. A person's attention may be for a second or less on a given object. The large amount of disorientation in the present and proximate surroundings which is coincident with the focusing of attention within a narrow

sphere, initiates orientation in the past and distant—initiates thoughts relative to the object attended to. A further focusing of attention, implying as it does an increase in the scope of disorientation in the present and proximate, results in an overlapping of thought on imagery. At this point the process is usually arrested and the person returns to his former state; the postures associated with the particular state of attention are undone, the functional scope of the sensory receptive apparatus is widened, and the person ready for another state of attention.

VIVIDNESS VERSUS ACCURACY

Thought, imagery and hallucination, in the order mentioned, are increasingly vivid and increasingly inaccurate subjective reproductions of actual past experiences. This increase in vividness, which goes hand in hand with an increasing inaccuracy, is corroborative of the present thesis and will be more conveniently explained in the following discussion of the anatomical and physiological substratum of the phenomena described in the foregoing.

UNDERLYING CAUSES

In the same manner that we trace the cause of the spiral form of the pine cone, of the rotations and revolutions of the heavenly bodies, of the eddy in the water and the whirlwind in the air to a collision of forces of different direction, with the resultant of an angular line of motion, so we can trace the reason for the same basic form of the different neuro-muscular conditions described in the foregoing to a single factor which is operative in all of them. Granting that we are in advance of that stage of civilization when thought, imagery and hallucination were taken to be due to a pervasion of the organism not merely by an unknown and by an unknowable force, we may be permitted to seek a sensory plane as that factor.

(1) The first stage of the different modes of behavior described above is a greater or less degree of disorientation in the present and proximate surroundings. Since it is the sensory receptive nerve apparatus which keeps the person or the animal "in touch" with these surroundings, we must conclude that the disorientation in question is due to some kind of disability of that apparatus.

(2) The second stage in each of the conditions described is the mental activity of thought, which may merge into that of imagery and the latter into hallucination. As has been stated, these mental functions are increasingly vivid and increasingly inaccurate subjective re-experiences of past actual experiences. This progressive increase in vividness and inaccuracy is in direct proportion to the extent to which sensory reception has been reduced. Since in the normal direction of nerve conduction the associative apparatus of the cerebral cortex—"the seat" of memories—is situated anatomically in advance of the sensory receptive apparatus, we must conclude on the basis of the clinical facts mentioned (a) that a diminution of the function of the latter nerve apparatus initiates the activity of the nerves of the association system; and (b) that an increasing diminution of the function of the sensory receptive apparatus results in a disorganization of the activity of the associative apparatus in which the separate items gain at the same time in vividness. The cause of the disorganization of memories—of the disruption of their mutual relations—is easily accounted for, on the basis of a large number of clinical facts, by their lack of guidance on the part of the nerve apparatus which keeps the person "in touch" with actual existences—the sensory receptive apparatus. The cause of the increase in the vividness of the disorganized memories lies, as will be presently seen, in that very fact—the defective functioning of the associative apparatus.

In anatomical relation with both, the sensory receptive apparatus and the associative apparatus, is the large nervous plexus of the thalamus and hypothalamus. All clinical and experimental evidence is to the effect that the thalamic plexus is the highest center of the basic vegetative autonomic functions of the body and, by virtue of that, of the emotions. This highest center of the emotions is largely under control of the associative apparatus of the cerebral cortex. Injuries to the latter, or injuries which sever its nerve connections with the thalamic plexus, by permitting a wider activity of the latter, result in an exaggerated intensity and vividness of the emotional coloring of experienced sensations.

The same functional defect of the associative apparatus in the later part of the second stage of the conditions in question, which is the cause of the disorganization of memories, results in its defective control of the functions of the thalamic plexus, with the consequence of an exaggeration of the emotional factors of intensity and vividness of the separate memories.

We have seen that a condition for the activity of thought is a reduction in the functioning of the sensory receptive apparatus to a point at which memories are guided by a large residuum of sensory reception along channels of actual existences, without permitting the latter to obtrude themselves unduly on the mental activity. Under such circumstances the associative apparatus still controls the display of thalamic function to a large extent, so that memories of past experiences are only slightly tinged by emotional coloring. Thought, therefore, in contradistinction to imagery and hallucination, although accurate with respect to relations of actual existences, is vague with respect to the colors, outlines, etc., of the existences themselves.

(3) The third stage in the conditions named is more or less profound uncon-

sciousness, testifying to a large reduction or suspension of the function of the associative as well as of the receptive nerve apparatus.

(4) With the reduction or the suspension of the function of associative apparatus, the function of nerve systems which are anatomically and physiologically situated in advance of them—the motor nerve systems—are activated. This is manifested by the postures and movements characteristic of each of the conditions described.

(5) The fifth stage is characterized in all of the conditions described by muscular relaxation. This testifies to a disability of the last link of the reflex arc, that which proceeds to the muscles.

SUMMARY

We thus see that the cause of the particular events, and their particular mode of succession, in the several conditions described in the fore-going, is a wave of disability, or inhibition of function, which floods in succession the several links of the reflex arc in the normal direction of nerve conduction, from the receptive, through the associative and to its muscular end. As the function of each of these links of the nerve pathway is reduced or extinguished, that of the next succeeding link is activated to a corresponding degree. After involving the muscular end of the reflex arc, the wave disability recedes, and it may be observed in a number of cases that recovery of function proceeds in a direction from the muscular to the receptive end of the nerve pathway. In the greater number of instances, however, the disability does not involve the entire reflex nerve pathway but after proceeding for a variable distance along it, recedes. The particular condition is in such instances short of one or more of the later stages. Such is notably the case in the instances of thought, of the

"startle," and of the minor epileptic seizure.

We have seen that in the instance of Jacksonian seizures, the person remains conscious and oriented. The disorder consists of a localized convulsion and subsequent relative flaccidity of the muscles involved. The occurrence of these seizures is corroborative of the present thesis. The cause of the disorder is a small tumor, a scar or other lesion in the immediate neighborhood of the motor area of the cerebral cortex. The wave of disability in these cases floods the nerve pathway from the motor area onward, leaving the nerve systems in the rear of it—the associative and receptive apparatus—intact. The person, therefore, remains conscious and oriented.

CONCLUDING REMARKS

Scientific eras, like political and economic eras, overlap, so that it is difficult to determine where one ends and the other begins. In the medical sciences of to-day, traces of medieval superstition may be discerned in the lingering tendency to view the more proximate causes of the mental functions with a degree of awe which forbids any other attitude toward them than one of adamant agnosticism.

This agnosticism must be largely dispelled upon finding that the apparently intangible mental functions can be aligned with others of a tangible nature. Upon analysis of a unit of thought we found that no matter how brief and subtle it may be, and how different it is in appearance from such a gross and cataclysmic occurrence as the major epileptic fit, it is essentially very much like the latter; both phenomena being constituted of the same events arranged in the same order. *The differences between them are mainly two: one, of magnitude; the other, of relevancy with respect to our well-being.*

LAND UTILIZATION IN COSTA RICA

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COSTA RICA, one of the smaller and least mountainous of the Central American republics, presents remarkable contrasts in relief, climate, vegetation, soils and land utilization within a short distance from the coast toward the interior. These differences are due primarily to the physiographic contrasts to be found in the area and to the resultant climatic provinces.

A traveler on the Northern Railway of Costa Rica will traverse most of the zones on the short trip from the coast at Limon to the capital at San Jose. In a distance of 103 miles the train traverses first the Atlantic coastal plain, then the foothills by means of a steep climb through the canyon of the Rio Reventa-

zon, then the highlands, crossing the Continental Divide (elevation 5,137 feet, or 1,566 meters), and finally descends upon the Costa Rican Meseta, an intermontane plateau, to the city of San Jose at an elevation of 3,800 feet. In few places in the world can so many contrasted zones be traversed in so short a distance.

PHYSIOGRAPHIC REGIONS

Physiographically the section of Costa Rica covered in this paper (Fig. 1) may be divided into three distinct provinces: (1) the Caribbean plain, (2) the foothills and volcanic mountain section of the middle cordillera, and (3) the Meseta or intermontane plateau. The coastal

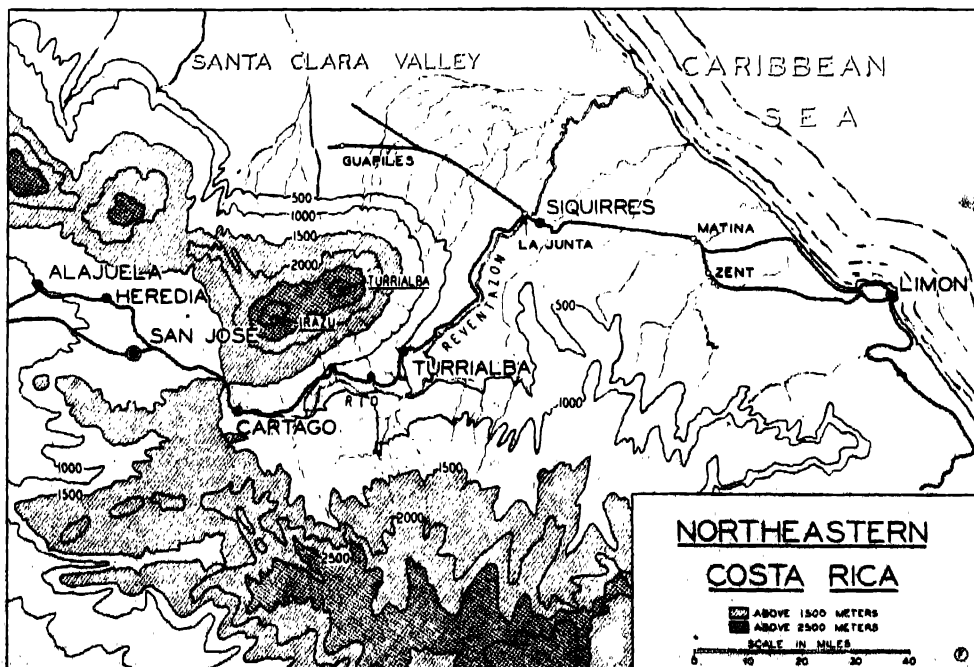


FIG. 1. MAP SHOWING ALTITUDE VARIANCE IN NORTHEASTERN COSTA RICA

plain, composed of slightly consolidated sedimentary rocks of Tertiary or Quaternary age, is flat and largely featureless. This plain is one of the most important provinces as it occupies nearly one third of the country. The northern part of the plain, which extends from the Nicaraguan boundary to south of the port of Limon, is extremely flat, being broken only by small hills, none of which are more than 1,100 feet above sea level. The central cordillera is divided by the canyons of the Rio Grande in the north and the Rio Reventazon about the middle of the country. The railroad uses the middle canyon of the Rio Reventazon to climb out of the coastal plain and cross the mountain range to the plateau. This central range or "Volcanic Range" consists of a number of volcanic peaks that increase progressively in height from Orosi (5,154 feet) in the northwest to Turrialba (10,995) and Irazu (11,325 feet) in the southeast in the vicinity of the Reventazon canyon (Fig. 1). This range is somewhat curved so that the summit-line describes a broad arc with the concave side facing the Caribbean. The Central Plateau, or Meseta, is covered by thick deposits of volcanic ash that provide excellent soils for the densely populated coffee country.

CLIMATE AND NATURAL VEGETATION

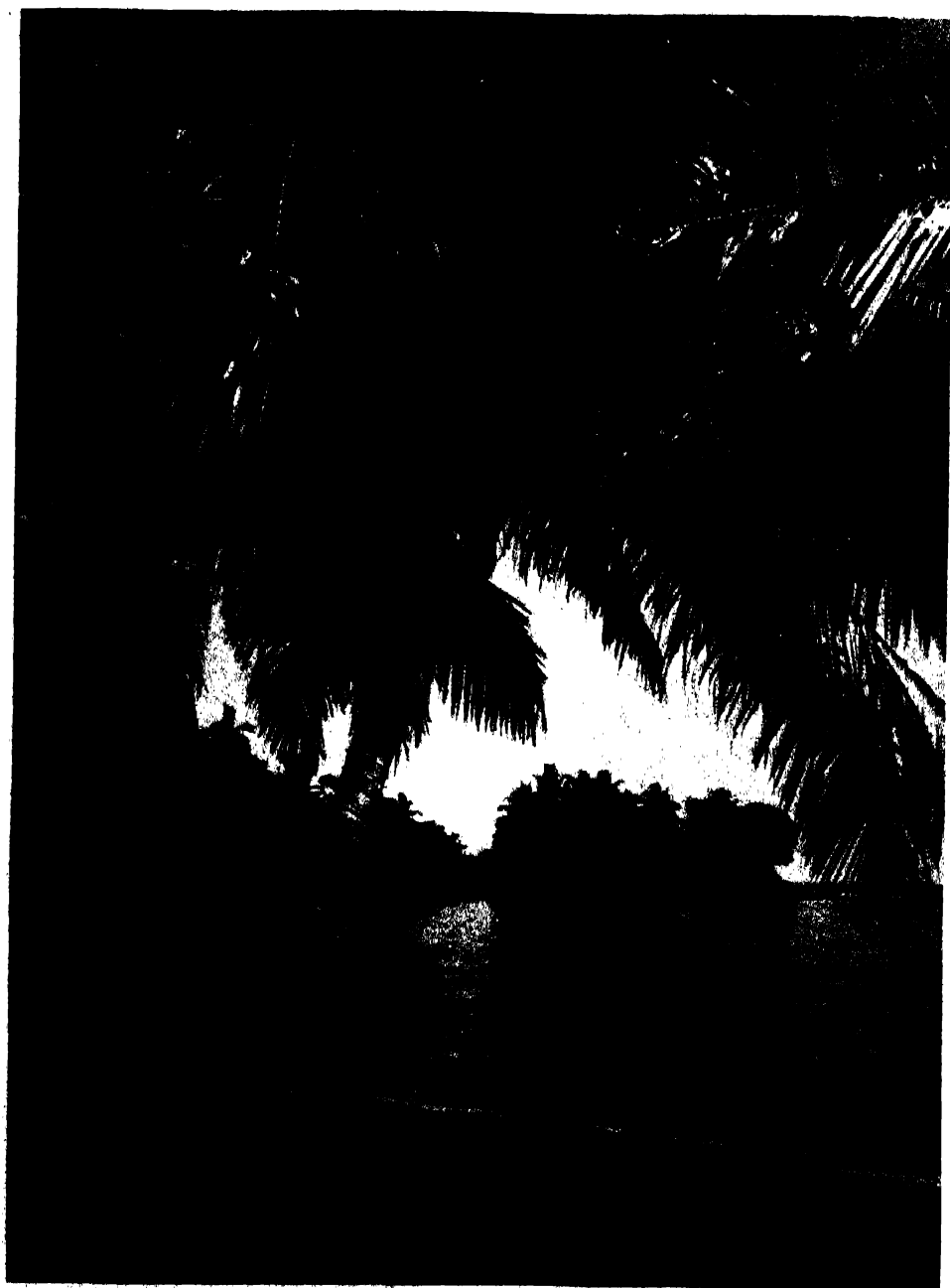
Although climatological data for all Central American countries are extremely meager, the climatic zones are well enough marked by contrasts in natural vegetation and land use to make possible the recognition of three distinct climatic types. The Caribbean plain with its heavy rainfall, high humidity and constantly high temperatures lies in the tropical rain forest region, a true "tierra caliente." This climatic zone, ideal banana and cacao country, extends up the slopes of the volcanic range to an altitude of about 2,000 feet. Above that

point the tropical high altitude or plateau climate begins. The entire white and Indian population of Costa Rica lives in this "tierra templada" region. On the upper slopes of the volcanic peaks a third climatic type, the "tierra fria," appears, but this zone is as yet unoccupied.

The natural vegetation responses to these climatic zones are quite definite. The Caribbean lowlands and lower slopes of the volcanic range are covered by the true selva. In the uncleared forests, and there are many of them in spite of the extensive banana and cacao plantations, tropical hardwoods dominate. This forest contains a wealth of species, many of which are valuable for furniture and cabinet woods. The most important trees are the Spanish cedar and the ceiba. The relative scarcity of mahogany in the Costa Rican rain forest is more than offset by the great abundance of Spanish cedar and other important cabinet woods. Forest resources of the area will continue to support an important and growing lumber industry. Associated with the large hardwood trees are vines, lianas and many parasitic plants, including the orchid. On the higher slopes of the "tierra templada" open forests of pine, oak and other species of the temperate regions appear. On the Meseta and in the smaller intermontane valleys, forests give way to grassland savannas. However, most of these areas have been under cultivation for so many years it becomes difficult to determine the original vegetation. The summits of the volcanoes are barren of vegetation.

COLONIZATION AND SETTLEMENT

Like the other Central American republics, Costa Rica was settled from the west coast, since the dense jungle along the Caribbean coastal plain made it almost impossible to reach the plateau

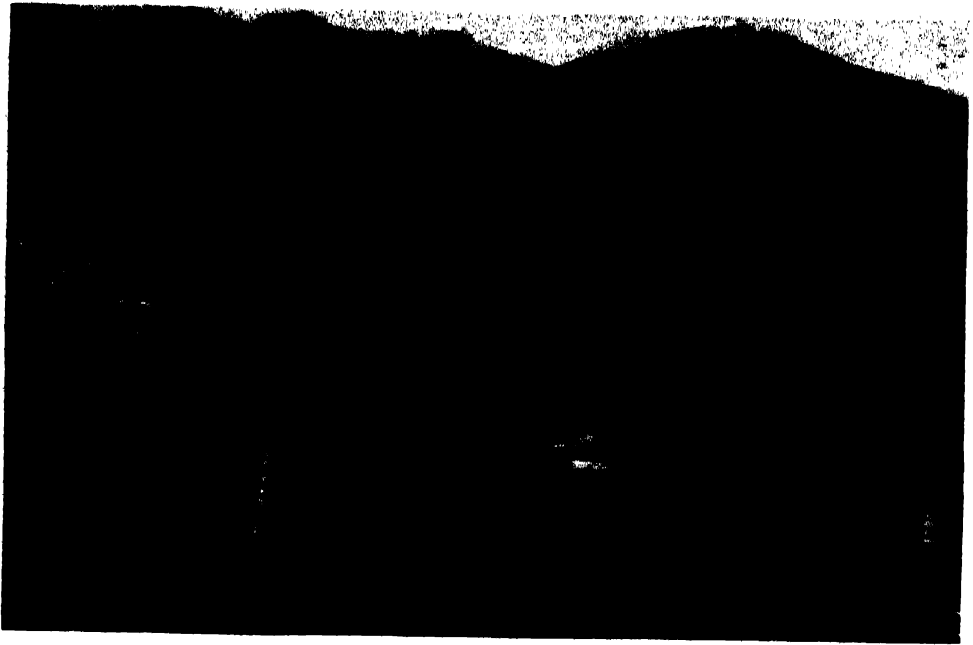


COCONUT PALMS FRINGE THE BAY AT LIMON

from that side. The first attempts at settlement by the Spaniards were at a point on the Pacific coast near the present site of Puntarenas. This settlement, made in 1524, was abandoned two years later, and from that date until 1560, no further attempts were made. However, in this interim the Spanish conquistadores did try to establish settlements on the Caribbean coast. Near the mouth of the Rio Sixaola, on the present Panamanian border, a settlement was made in 1540, and three years later a second one was established on the lower Rio Reventazon. From that point the Spaniards attempted to go inland to the plateau along the Reventazon Valley, but the party was overwhelmed by the wild forest Indians of the jungle area. These two Caribbean coastal settlements were then abandoned (1544) and no further attempts to occupy this coast were made until near the close of the nineteenth century, more than three hundred years later.

In 1560 two expeditions were sent out from the *Audiencia* of Guatemala to each coast of Costa Rica. The one to the Caribbean coast failed to reach its destination, but the other established a base on the Pacific coast and moved up the steep western slope of the mountains to the Meseta Central. The Meseta Central is divided into a western (Occidental) and an eastern (Oriental) division (Fig. 1), by a low water parting at the Continental Divide. The expedition crossed over the Divide and made the first permanent white settlement in Costa Rica at Cartago (1563) in the Meseta Central Oriental near the headwaters of the Rio Reventazon. The colony flourished, but due to its extreme isolation from other Spanish settlements of the time, its growth was slow. The Indians of the plateau country were never numerous. An estimate during the early part of the sixteenth century placed their number at about 27,000. They were rapidly ab-

sorbed by the whites or were deported to Panama or Peru so that to-day the republic contains fewer than 4,000 pure Indians. With the lack of Indian labor in the plateau country and the extreme isolation of the first settlement, the Spaniard of the Meseta, in contrast to the Spaniard in Mexico or Peru, had to do manual labor and become self-supporting. The early settlers of Cartago included Spanish women, quite in contrast to most early settlements, and this insured a dominantly white population from the beginning. In spite of its name, no fabulous riches were found in Costa Rica, hence Spain seemingly forgot or at least ignored this small colony, placed high in the mountains on the eastern slope of the Continental Divide. For more than a century no further white settlements were made in Costa Rica, although several parishes, based on Indian villages, were established on the Pacific slope. Further attempts to establish contacts with the Caribbean coast by way of the Rio Reventazon Valley failed because of the impenetrable jungle and the wildness of the Indians. Thus the Spaniards in Cartago had to content themselves with remote contacts with Spain via the west coast and Panama, and turn their backs on the east coast. It is interesting to note that Cartago is only eighty-six miles by rail from the Caribbean port of Limon, yet that distance was never bridged by white man until toward the close of the nineteenth century. The building of the railroad (1871-1890) connected Cartago (1563), the oldest white settlement in Costa Rica, with Limon (1880), one of the most recently established cities of the republic. For more than a century after the founding of Cartago no further settlements were made by Spain, but in the early part of the eighteenth century active colonization began to radiate from Cartago. Having turned their backs on the Caribbean coastal region, the next

RAILWAY BRIDGE IN THE HIGHLANDS¹

colonists recrossed the Continental Divide and established themselves on the drier and more fertile Meseta Central Occidental. Not only was the land of this area better suited to agriculture and habitation, but it was nearer the mother country by the Pacific coast route. It seems strange that it took the Spaniards nearly 150 years to realize this, but one wonders whether during that time they were not hoping to establish contacts with the Atlantic coast. New settlements were made at Heredia (1706), San Jose (1736) and Alajuela (1790). By 1835 the population figures of districts dominated by these four settlements were as follows:

San Jose	23,606
Cartago	19,700
Heredia	15,262
Alajuela	8,980

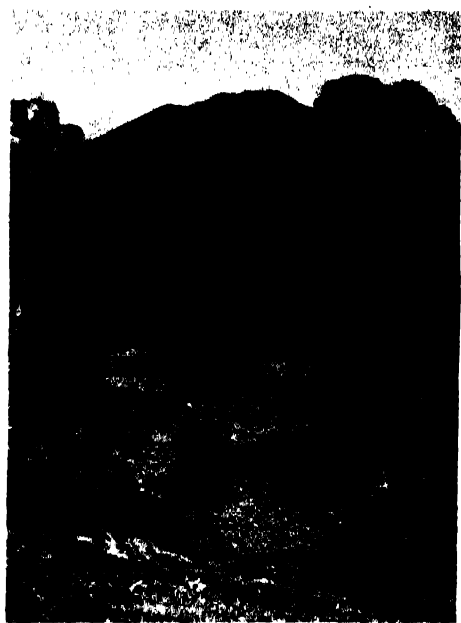
In the early part of the nineteenth century Costa Rica separated from Spain and established a republic. The capital

¹ Photographs obtained through the courtesy of the Pan American Union.

was moved from Cartago to the larger and better located city of San Jose. The history of the republic from the time of its independence to the latter part of the nineteenth century is one of many revolutions. Several attempts at unifying the Central American states into one nation failed. After the William Walker incident, Costa Rica, with its highest percentage of white population, emerged as a well-organized republic. The dream of the founders of Cartago three centuries earlier to connect the plateau with the Caribbean coast was still cherished, and in the early 1870's work was begun on the railroad down the Reventazon Valley to the coast. The increase in population on the plateau had caused the whites to spill out of this high basin and flow down the Reventazon Valley as far as Turrialba.

THE BUILDING OF THE RAILROAD

In 1871, Don Tomas Guardia, dictator of Costa Rica, determined to build the



TURRIALBA VOLCANO

railroad to the Caribbean coast. He invited Henry Meiggs, builder of several railroads on the west coast of South America, to undertake the task. Meiggs gave the contract to his nephew, Henry M. Keith, who immediately sent for his younger brother, Minor C. Keith. Arriving on the Pacific coast in 1871, the Keiths proceeded by mule to San Jose, and then on down the east slope of the mountains to the Caribbean coast. The journey from San Jose to the coast required seven days of untold hardships. At that time the Costa Ricans had a saying that "the first time a man made a trip over this trail he was a hero, but if he did it a second time he was a damned fool." Minor Keith made many trips over the trail, and in the course of twenty years built the railroad to the coast.

In 1871 there were no ports on the Caribbean coast. The site of Limon was a flat, swampy area with an extremely unhealthy climate. It offered no good harbor, but being possibly the best place

along the coast for the tidewater terminus of the railroad, it was selected as the starting point. The Indians of the region would not work, and the whites and Indians of the plateau could not be persuaded to go to the unhealthy lowlands, hence all labor as well as most of the supplies for the new railroad had to be imported. Keith secured the first shipload of laborers from New Orleans. Of more than two thousand white men brought in at that time, few survived. Jamaica Negroes, the next laborers imported, proved to be capable workers in the tropical rain forest. About that time the French began work on the Panama Canal and offered higher wages for labor. Most of the Jamaica Negroes deserted and went to Panama. Keith then contracted for two thousand Italian laborers, but these were unsuccessful, and after a time the surviving ones chartered a ship and returned to Italy. By that time the French enterprise in Panama had failed and the Jamaica negroes returned to Costa Rica. This insured sufficient labor to complete the railroad. In addition to labor troubles, Keith had many financial difficulties. His own credit and that of the Costa Rican government were endangered numerous times, but the Costa Rican people came to his rescue at the critical times, and in the end he paid back their money and gave them the railroad to the plateau.

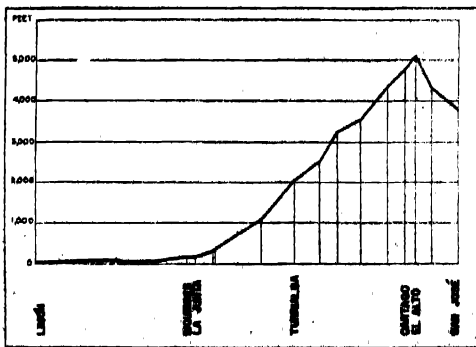


FIG. 2. PROFILE ALONG THE RAILROAD

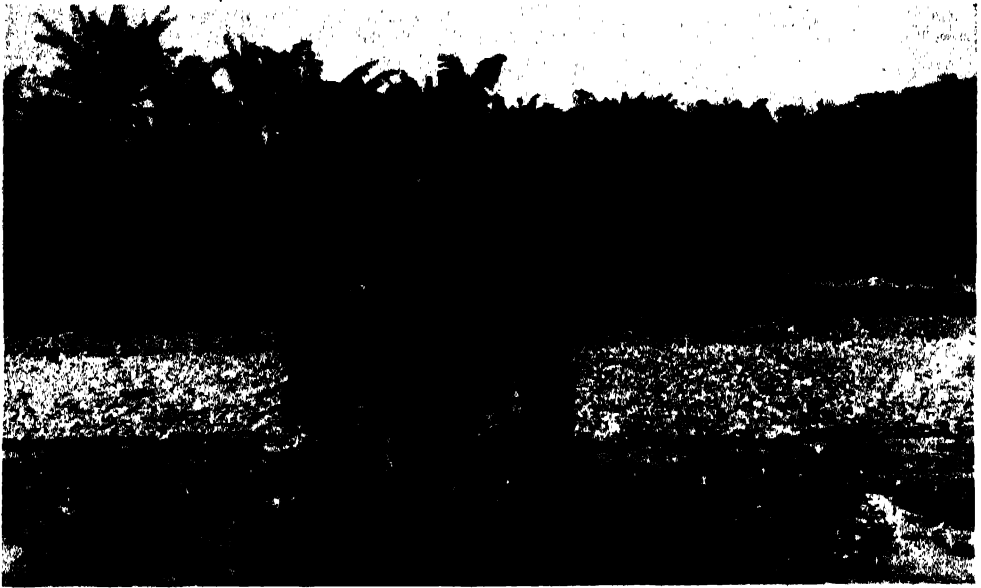
Once during the construction period operations were suspended for nearly three years while Keith spent that time in England trying to raise more money to complete the line.

The original plan for the road led westward from Limon along the north flank of Turrialba Volcano to Rio Honduras Valley and thence over the pass to San Jose. The line was completed to Rio Sucio, about seventy miles from Limon, by 1882. Keith had to finance the operations out of his own funds. During that period, when further construction was stopped, banana plantations were begun, to provide the partly completed railroad with a commodity for export. Being unable to tap the coffee country on the Meseta, Keith created traffic by planting bananas extensively in the Matina and Zent Valleys near the coast, and on the Santa Clara Valley on the north flank of Mount Turrialba (Fig. 1). This was the beginning of the great banana industry of Central America. Shipments were soon made by steamers to New Orleans and to New York. By the time construction was again started on the main line to the plateau, a new route had been

selected. The old plan to go around the north side of Mount Turrialba and through the pass to San Jose was abandoned in favor of the southern route up the Reventazon Valley through Cartago and over the Divide to San Jose. This new route branched off from the original line west of Siquirres and immediately began the ascent of the Reventazon Canyon. The old line from Siquirres, although now only a branch, has continued to be one of the best revenue sections of the entire system because it serves the fertile Santa Clara Valley. The chart (Fig. 2) shows the profile of the main line of the railroad from the coast at Limon to San Jose. From Limon to La Junta, at the entrance of the Reventazon Valley, the grade is gentle, La Junta, 39 miles from Limon, being only 187 feet above sea level. In the next 24 miles to Turrialba the road climbs steadily to an altitude of 2,037 feet above sea level. From Turrialba through Cartago to the summit of the Continental Divide (5,137 feet above sea level), the climb is 3,100 feet in about thirty miles, with steep grades and sharp curves. This section of the road, the most expensive to build



A SLEEPY MOUNTAIN VILLAGE ON THE HIGHWAY



TRANSPORTING BANANAS TO THE RAILROAD

and operate, is the most scenic part of the route. From the Continental Divide the road drops to San Jose at an altitude of 3,800 feet. In 1890 the railroad was completed and the first trains were run from San Jose and Cartago to the Caribbean coast. Cartago was connected at last with the Atlantic Coast, New York and Europe, 327 years after it was established. This ushered in a new era for Costa Rica, as it removed the plateau settlements from extreme isolation to one of easy contact with the outside world. The railroad provided not only passenger service to and from the plateau, but also an easy outlet for coffee and other products of the plateau, as well as for the bananas and cacao of the Caribbean lowland. Later a similar although shorter line was built westward from San Jose to the Pacific port of Puntarenas. With the completion of this line, Costa Rica had one of the three transisthmian railways of Central America. The road to the Pacific coast has not produced the revenue of the Caribbean line because of direction and because of the lack of com-

modities to be shipped from the Pacific coastal lowlands.

LAND OCCUPANCE AND LAND UTILIZATION

From the point of view of land occupancy and land utilization, three zones may be recognized. (1) The Caribbean coastal plain, dominated by forests, but containing the large banana plantations and the extensive production of cacao, as well as a growing timber industry. (2) The Meseta Central, open country with few trees, either in grazing activities, or, if in crops, dominated by coffee, with numerous subsistence crops. (3) An intermediate zone, not too well defined, that combines some of the qualities of each of the other two zones. This intermediate area is found along the Reventazon Valley, with the lower slopes producing some bananas and cacao. On the higher slopes, coffee becomes important, with banana palms used only to shade the coffee trees and not grown for their fruit. This area is truly a transitional zone.

The Caribbean coastal plain was the

land of the tropical rain forest and the forest Indian until after the beginning of the construction of the railroad. The railroad company, as has been shown, needing some commodity to transport, established banana plantations along its right-of-way and initiated the development of the great banana industry. While this area is still an important producer of bananas, it has declined because of soil depletion and competition with more recently cleared areas. Cacao, grown in this area for a long time, did not become important until after the decline of the banana industry. Since cacao trees require substantially the same climate as the banana, they can be planted in lands where the banana was formerly important. The area is an agreeable habitat for the Jamaica Negro, who came into these lowlands to build the railroad and remained to grow bananas and cacao. The Negro problem is becoming one of increasing proportions since they are advancing farther up the railroad toward the plateau. At present the color line between the native whites and Indians of the plateau, and the imported Jamaica Negroes of the lowlands is reached at about 2,000 feet in the town of Turrialba. Below this town more than 90 per cent. of the population is Negro; above, over 90 per cent. is white or Indian. This introduction of great numbers of Negroes into one of the few predominantly white countries of the tropics has been called by one writer an "ethnological crime similar to that committed by the old European slave traders." The fruit company introduced thousands of Negroes into the area and failed to repatriate them. One wonders, however, who would cultivate the bananas and cacao if the Negroes were deported.

The Meseta Central presents a picture entirely different from that of the Caribbean lowlands. Settled by the Spaniards in the sixteenth, seventeenth and eight-

eenth centuries, the population is dominantly white. Since the Indians of the plateau were never numerous and made poor agricultural workers, the white settlers had to do their own work on the farms. Extreme isolation and retarded immigration caused the land holdings to be broken into small farms. Coffee is by far the most important crop, and has been for a long time. The Costa Rican Meseta is one of two important coffee-producing areas in Central America, the other one being in the highlands of Guatemala. For a long time the coffee of this region moved to the European market, since Americans, being accustomed to cheaper grades, would not pay the price for high quality coffee. Increasingly larger quantities of "mountain grown coffee" are finding their way into the United States and are creating a demand for higher quality coffee. In addition to the many coffee "fincas" or estates, subsistence crops such as corn and beans are grown, and an important grazing industry has developed. Near the cities dairies have become well established. These are usually quite modern, though milk is still delivered in San Jose in cans fastened onto the back of a burro. The plateau area combines the modern and the primitive in a pleasing way, particularly as regards transportation. In San Jose one may see the modern railroad, street car and automobile, and alongside these the cumbersome, solid-wheel coffee carts drawn by a team of oxen.

Land use in the intermediate zone is less distinct than in the two zones already considered. As one reaches the upper limit of the wet tropics at about 2,000 feet elevation, banana plantations, cacao plantations and the ubiquitous Negro drop out of the picture, to be replaced gradually by coffee fincas, cattle ranches and white people. The complexion of the population changes abruptly near Turrialba, and throughout



NATIONAL THEATER SEEN THROUGH ARCADE OF HOTEL COSTA RICA

the intermediate zone as well as on the Meseta the population is dominantly white, with some Indian and some Mestizo strains. In this area, near the town of Turrialba is grown the delicious sugarloaf pineapple that is served to passengers as the train stops at the station, but for some reason the fruit is not exported. Some day Costa Rica may recognize the value of this high quality fruit, which is far superior to Hawaiian pineapple, and will market it in the United States. This zone represents the lower limit of white settlement from the plateau and the upper limit of Jamaica Negro occupancy from the wet tropical lowland. One wonders if the white Spanish population of Costa Rica, being transitional in character, will be able to hold its own in the area, or be displaced and forced to retreat to the plateau by the advance of the Negro.

CITIES—CONTRASTS IN URBAN DEVELOPMENT

The towns and cities of the three zones

show marked contrasts in development and reflect the environment of each zone as truly as the rural landscape. The towns and villages along the railroad may be grouped as follows: (1) Caribbean lowland towns, Limon and Siquirres, (2) intermediate zone, Turrialba, and (3) plateau cities, Cartago and San Jose (Fig. 1). Only one town in each region will be considered.

Limon is truly a city of the rainy tropics, but because of money spent by the railroad and the fruit company it has good sanitation and paved streets. Along the sidewalks are colonnades to protect one from the sun and heavy rains, and most of the houses have a second story with balcony extending over the sidewalk. Large open doors and windows allow a maximum of air to circulate. Buildings are of wood or stucco, but are usually covered with a corrugated iron roof of sufficient pitch to turn the heavy rains. Everything considered, they show a definite response to heavy rains, high humidity and bright



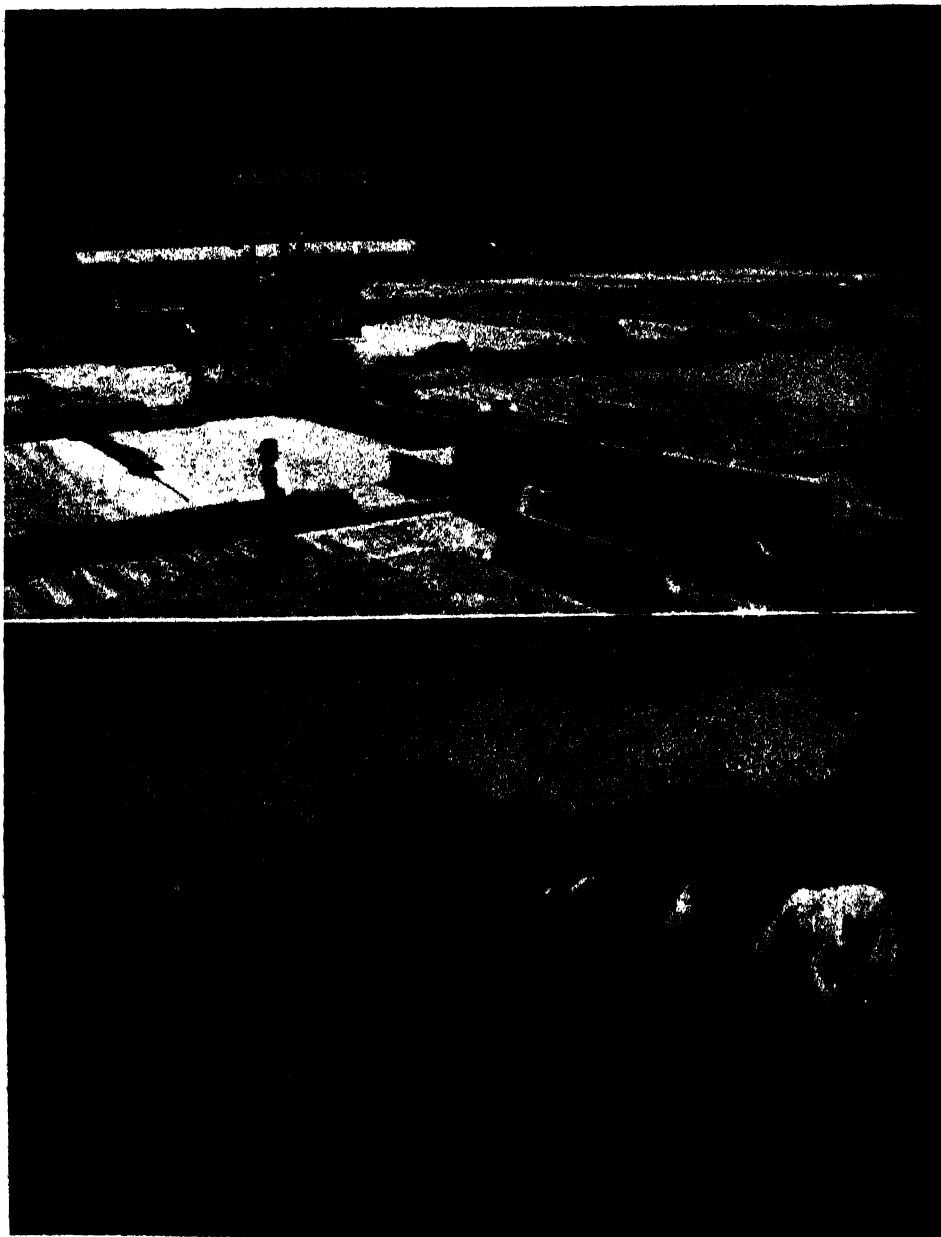
A VIEW OF CENTRAL MARKET IN SAN JOSE

sunshine when it is not raining. The docks, modern steel and concrete structures built by the fruit company, can accommodate several boats at the same time. The main dock is equipped with modern banana-loading machinery. A point of interest is Vargas Park, a small botanical garden in the heart of the town. Since the population of Limon is more than 90 per cent. Negro, it is not in any respect a Costa Rican town, but resembles most coastal cities of the Caribbean.

Turrialba, the only town of the intermediate zone, is smaller than Limon. Its population is greatly mixed, since it is near the color line. Settled originally from the plateau, the still dominant white population is being gradually crowded out by the ever increasing Negro. The houses are dominantly of wood and are one-story. The roofs, usually of corrugated iron, are less steep than those of Limon. The native population that meets all trains, offering pineapple and other foodstuffs for sale—or begging for money—are a mixed lot,

showing the cosmopolitan nature of the population. Turrialba is primarily a way station on the railroad, but it is also a fairly thriving agricultural center.

San Jose, in the Meseta Central Occidental, presents a marked contrast to either of the above-mentioned places. Although considerably younger than the original settlement of Cartago, it has profited from being the capital of the country for the last century and has received more benefits than other cities. Although located in the earthquake belt and damaged several times by severe tremors, the city has never suffered the complete destruction that visited Cartago in 1910. San Jose is well planned with wide, paved streets, and is dominated by substantial one- and two-story stone buildings. Although "tin" roofs are increasing in number, the tile roof is still important. With less rainfall than in the other cities, flat roofs are in evidence. San Jose has numerous government and public buildings that would do justice to a city many times its size. All in all it is a true capital city of the plateau



CLEANING AND DRYING COFFEE IN THE HIGHLANDS

country, and on a small scale resembles Mexico City or Havana.

THE RESORT INDUSTRY

Costa Rica is making every effort to attract tourists. The excellent weekly steamship service of several lines calling at the ports of Limon and Puntarenas and the regular service of Pan-American Airways are giving the country contacts with the United States and other parts of the outside world. The railroad to the plateau from either coast provides the tourist a scenic trip to the capital city and other points of interest on the plateau. In addition Costa Rica is beginning to build good highways into the mountain country. The government has not been slow in recognizing the advantages gained from tourist trade, and by means of the National Tourist Board of Costa Rica is making every effort to acquaint the world with the country. Truly this republic is shaking off the

bonds of isolation that it endured for more than three centuries after the founding of Cartago.

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BOTANICAL GARDENS AND MAN

"MAN was lost and found in a garden!" In a garden may be found both rest and refreshment to soul and body and also inspiration with opportunities for reflection and research.

This applies to the humblest plot as well as to the botanic garden, and much may be learnt from a careful study of the development of the commonest weed. In the botanic garden where "Every tree that is pleasant to the sight and good for food" may be grown, as well as those of service to mankind, as the source of drugs, spices, beverages, fibres, timbers and such like, the educational possibilities and openings for research are far greater.

The search for plants yielding drugs and spices led to the foundation of botanic gardens; for in the monastic gardens of the Middle Ages—the forerunners of the botanic gardens attached to the universities—the cultivation of "simples" was one of the chief concerns of the community. Interesting survivals of these early physic gardens may still be seen in the Botanic Garden at Padua, and the Apothecaries' Garden at Chelsea—the Chelsea Physic Garden.

The search for spices has caused men to travel far and wide over the surface of the earth, has destroyed monopolies in the trade in economic products derived from plants (cloves, nutmegs, cinnamon, etc.), and has led to the establishment of gardens for their cultivation and exploitation. In this way many of the tropical botanic gardens have come into being, and through their efforts new markets have been opened for the drugs, spices and other economic products, native to one particular locality and under the control of one nation.

Botanic gardens, wherever they may be situated, should be the Mecca to which we turn for correct identifications of plants of economic value. They should also be a source of supply, both of economic and decorative plants, to other gardens or countries for the general good of mankind. Would that in these anxious days we could find and distribute that tree "whose leaves were for the healing of the Nations!"—*Arthur W. Hill (Director, Royal Botanic Gardens), Journal of the New York Botanical Garden, August, 1941.*

BONDING THROUGH HYDROGEN

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ONE of the most remarkable achievements of man's mind is the proof that all material things known to him are in the last analysis composed of a surprisingly few distinct elementary particles. No less an achievement has been the knowledge man has gained of the nature of the bonds which tie these few particles into the myriads of combinations which form the world he sees.

These bonds may be divided into three classes: those which bind the elementary particles into the nuclei of atoms, those much weaker ones which tie atoms together to form molecules, and the still weaker ones acting between molecules and between different parts of the same molecules. The first of these, the nuclear bonds, require such great forces to disrupt them that only in recent years has it been possible to do so. Considerable attention is now being focused on them. The second of these, the electrovalent and covalent bonds between atoms, can be made and broken with such forces

as heat and electric potential available in the ordinary laboratory. A great amount of study has been given to them, and much has been learned about their nature. Because of the relatively small energy involved in the third class of bonds there is a tendency to underrate their part in determining the structure and properties of matter. The physical and chemical changes which require so little energy that they take place freely under ordinary conditions of temperature, pressure, etc., are among those which are of greatest significance to man. One of the most important types of these weak bonds comes about through the sharing of the positive charge, or proton, of a hydrogen atom between two atoms, *X* and *Y*, either of the same molecule or of different molecules, to form a bond between *X* and *Y*. Such a linkage is usually termed a hydrogen bond or a hydrogen bridge. Because of the abundance of hydrogen and of the atoms found to participate in hydrogen bonding—carbon, nitrogen, oxygen, fluorine, chlorine and sulfur—these bonds occur in many different phases of science. Their prevalence, however, has only recently begun to be realized.

Association between like and unlike molecules produces abnormalities in many physical properties of compounds—boiling points, freezing points, viscosities, dielectric constants, vapor pressures, solubilities, heats of mixing, of fusion and vaporization, etc. As data accumulate it becomes increasingly obvious that the most frequent cause of association is the hydrogen bond. Water, if it were not associated through hydrogen bonds, would be a gas at ordinary temperatures,

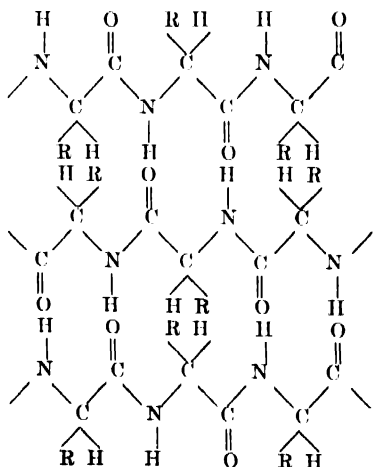


FIG. 1

and hence life as we know it would be impossible. Furthermore the function which this substance has in both plant and animal life is very largely dependent upon its ability to donate as well as to accept protons in the formation of hydrogen bonds. In addition, alcohols, phenols, oximes, amides, amino acids, certain of the amines and other organic compounds have long been known to be associated because abnormalities were found in their physical properties. From recent measurements of infrared absorption spectra this association has been shown to be of the hydrogen bond type. Furthermore, other large classes of compounds which do not have a proton held loosely enough to be shared in hydrogen bridges—nitriles, nitro compounds, esters, aldehydes, ketones, ethers and certain amines—have been found to form complexes with other atoms by accepting a proton in hydrogen bond linkage. The importance of the latter classes of solvents to industrial chemistry is well known, and their use as solvents is in many instances dependent upon their ability to form complexes with the solute through hydrogen bonds.

The phenomenon of chelation, or the formation of rings within molecules, of wide occurrence in organic chemistry, affects the physical properties as well as the chemical reactivities of the compounds in which the chelated rings are formed. Hydrogen bonding is often the cause of chelation, as in *o*-nitrophenol, salicylaldehyde, methyl salicylate, *o*-hydroxyacetophenone and the enol form of acetylacetone.

Proteins, tissue builders in the body, are now believed to be held in their native configurations by hydrogen bonds. X-ray diffraction work¹ gives evidence that protein molecules are composed of elongated backbone structures, somewhat as shown below (Fig. 1):

¹ See, for example, Ashbury, "Fundamentals of X-ray Structure," Oxford University Press, 1941.

In these structures it is probably hydrogen bonding between the NH and C=O of the adjacent chains which ties the chains together. The arrangement of the chains as shown by the x-ray work indicates this but does not definitely prove it since the x-ray patterns fail to reveal the position of the small hydrogen atoms. Infrared absorption spectra show that the NH group in simpler compounds like pyrrole will share its proton in hydrogen bonding and that the carbonyl group in simple compounds like acetone

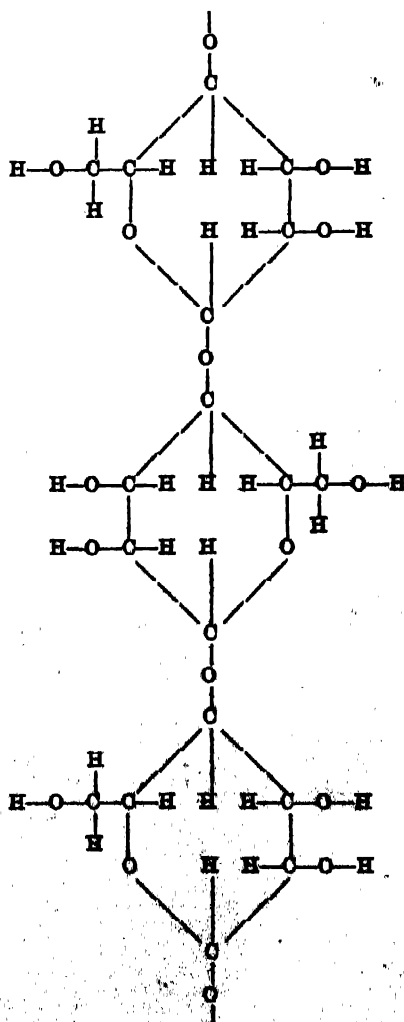


FIG. 1

will accept a proton readily. These studies lend credence to the belief that hydrogen bonds occur thus in the proteins. Spectroscopic studies of the proteins themselves are now being made and should prove fruitful, as observable effects on the vibrational bands of both NH and C=O groups are produced by hydrogen bonding.

Cellulose is made up of glucose rings arranged in chains, somewhat as Fig. 2 shows.

Studies of compounds like water, alcohols and carboxylic acids indicate that the OH group is a powerful hydrogen bonding agent. The presence of the OH groups along the sides of the cellulose chains suggests that hydrogen bonding is present and probably ties the cellulose chains into bundles, which in turn compose the cell walls of almost all plant structures. Appearing in such natural forms as wood and cotton and in such synthetic products as rayon, explosives and picture films, cellulose is sufficiently useful to justify extensive studies of the hydrogen bond theory.

Likewise, the prevalence of OH groups in biologically important compounds like starches and sugars suggests that the hydrogen bond is significant in determining their structure and properties.

In the popular Brønsted-Lowry theory, which defines acids as proton donors and bases as proton acceptors, the normal acid-base reaction is represented as the transfer of a proton from the acid to the base. The strength of an acid is defined in terms of its tendency to surrender protons to a given base, and the strength of a base in terms of its ability to capture protons from a given acid. It is extremely advantageous to think of the hydrogen bond theory somewhat as an extension of the Brønsted-Lowry theory. When hydrogen bonds are formed, proton donors and proton acceptors, acids and bases, participate, but here the proton is only partially surrendered by the

acid and only partially captured by the base. Indeed, the formation of a hydrogen bond may be regarded as an intermediate step in the complete transfer of the proton. Many chemical reactions catalyzed by acids and bases are no doubt caused by a shifting of electrical charges in the molecule, a shifting which results from the formation of temporary hydrogen-bonded complexes.

It is significant that hydrogen bonding has been found to occur only when the proton acceptor atom has an available electron-pair. It appears that the proton must interact in some way with the electron-pair. There are at least two possible ways in which this interaction may take place: while remaining bound through an ordinary electron-pair bond to one of the atoms, the proton may interact electrostatically with the electron-pair or electron-cloud on the second atom; in many instances quantum mechanical resonance may be involved, in which the proton is bound through a covalent bond first to one and then to the other of the atoms, many times each second. The hydrogen atom because it has only one stable orbital can not form two covalent bonds at the same time.

Although the hydrogen bond can be studied in many different ways through its varied effects on the physical properties of substances, the most widely used method of approach is that of infrared absorption spectroscopy. As suggested above, proton donors and proton acceptors in hydrogen bonding may be considered as acids and bases. The base here weakens the bond between the acid and its proton but does not break it completely. The stronger the base, the more the bond of a given acid is weakened. Fortunately the decrease in strength of the acid bond is readily revealed in its infrared absorption spectra. For simplicity we may compare the proton vibrating against the remainder of the acid molecule to the oscillation of a

weight suspended to a spring. If the spring is made weaker, the weight vibrates more slowly, at a lower frequency. Similarly the weakening of the acid bond by the base causes the vibrational band of the acid group to shift to lower frequencies. The stronger the base, the more pronounced is its effect on the vibrational band of the proton donor group. By measurements of the shifts, estimates of the strengths of the hydrogen bridges may be obtained. Comparisons of infrared data with data obtained from measurements of other physical properties have revealed some interesting correlations.³ For example, linear relationships have been found to exist between the shifts which several different basic solvents produce in the OD vibrational band of CH_3OD and of D_2O and the logarithms of the basic ionization constants of the solvents. These relationships promise to be extremely useful in the determination of basicity constants of numerous organic compounds, and they show how hydrogen bond forming ability is dependent upon basicity and acidity. Other relationships which have been found will likely be of value in estimating solubilities of compounds, electronegativities of atoms, chemical reactivities, etc.

Investigation of the hydrogen bond is a most promising field of research for chemists and biologists as well as physicists. Despite the large amount of data accumulated on the subject, the nature of the hydrogen bond is still somewhat uncertain. Its uses in the study of reaction mechanisms, solubilities, acids and bases, and the role it performs in biologi-

cal phenomena are just beginning to be explored. Bonding through hydrogen is probably significant in the rising of sap in plants, in muscular contraction in animals, and in the transmission of messages through nerves to the brain. Recently Professor Linus Pauling has stated his belief, "As the methods of structural chemistry are further applied to physiological problems it will be found that the significance of the hydrogen bond for physiology is greater than that of any other single structural feature."⁴ Something of its scope in the field of organic chemistry is suggested by the following statement of Dr. M. L. Huggins. "Many properties of organic substances which have been vaguely attributed to 'van der Waals forces,' 'polarity,' 'steric hindrance,' 'catalysis,' are definitely due to the formation and existence of hydrogen bridges. . . . The most fruitful applications of the hydrogen bridge theory will be a better understanding of the nature and behavior of complicated organic substances such as gels, proteins, starch, cellulose sugars and other carbohydrates, chlorophyll, haemoglobin and related substances, etc."⁴

As electrons, smallest units of negative electricity, tie atoms together to make molecules, so the proton, smallest unit of positive electricity, ties molecules together to make super-molecules. And with new instances being constantly discovered it begins to appear that the hydrogen bond is second in importance only to the electron-pair bond.

³ Linus Pauling, "The Nature of the Chemical Bond," Cornell University Press, Ithaca, N. Y. 1939. p. 265.

⁴ M. L. Huggins, *Jour. Org. Chem.*, I, 407 (1936).

² W. Gordy and Spencer C. Stanford, *Jour. Chem. Phys.*, 9, 204 (1941); W. Gordy, *Ibid.*, 9, 215 (1941).

SOCIOLOGY AND THE OTHER SCIENCES

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MOST scientists, including many sociologists, believe that the theoretical and practical problems of sociology are more "difficult" or much less well systematized than is true of some other social sciences such as law, economics¹ and even political science. Most scientists would agree that the physical and biological sciences are vastly superior in this respect to all the social sciences.

I have long believed it both plausible and profitable to deny both of these views.² The case for the maturity of law, economics and politics is easily destroyed by considering the present war of words in these fields. In recent years, neither their practical recommendations nor theoretical formulations have been particularly convincing to a world floundering in legal, political and economic confusion and disaster. Much of what has passed, and still passes, for scientific knowledge in these fields is mere verbalized hunch and hope, fear and hate, and speculative constructs of the tongue in bondage to the culturally conditioned gut. More conventionally stated, these formulations are not the result of empirical research but are the expression of the ideologies, the folkways and mores, the personality and culture patterns of their originators. They are the projective, reified verbiage of impatient, fearful or hopeful men. The ideologies of Marxism, Nazism, Capitalism, Democratism, etc., are more like religion than science.

¹ V. Pareto, "The Mind and Society," New York, 1935, holds that jurisprudence and "pure" economics are the only social sciences which are at all exact and well developed (Sec. 824, 2011).

² Read Bain, *Social Forces*, I, December, 1929, 222-231; II, March, 1930, 369-378; *Publ. Amer. Sociol. Soc.*, August, 1932, 155-164.

As yet, law, economics and politics have produced few valid scientific universal generalizations; they are the verbal, valuational handmaidens of particularisms, the hortatory spokesmen of going, growing or dying legal, political or economic structures.

Actually, there is no such social reality as a legal, political, economic or even a politico-economico-legal order. Social reality is an organic compound of these and a finite number of other distinctive interacting factors. Perhaps the greatest single theoretical contribution of sociology is its emphasis that all single-factor analyses of social phenomena are inadequate. The evidence for this statement is the development of sociological jurisprudence, institutional economics, cultural anthropology, social psychology, social history, human geography and even sociological interpretations of religion, graphic art, literature and music. This *organic cultural interaction* concept of social phenomena is one of the major historic revolutions in human thought, ranking with gravitation, evolution, the cellular hypothesis, synthetic chemistry, endocrinology, immunology, radioactivity and physical relativity. It takes time for such revolutionary conceptions to register their full effects. We have not realized as yet all the implications of this organic interaction concept, not only for the social sciences but for all other sciences as well. I already have indicated some of its marked effects upon the social sciences; its effects upon the biological sciences are not so obvious and many would deny that it has had any on the physical sciences. Space prevents more than a brief discussion of these points.

The organic cultural interaction the-

ory of human behavior has wrought havoc with some of the once generally accepted biological theories. One need only mention its effect on the doctrines of instinct, race differences, psychosomatic diseases, natural selection, evolution applied to human groups (social Darwinism), rampant eugenism, hereditary traits⁸ and all forms of biological determinism. In this revision, many biologists took the initiative and psychology also played a part—but it was a sociologized psychology. *Tiersoziologie* and plant and animal ecology have been crossfertilized by sociology with mutual benefit. Sociologists have been greatly helped in developing their theory of organic cultural interaction by such men as Pavlov, Freud, W. M. Wheeler, Child, Allee and many others. At least the last three are also directly indebted to sociology. All science is interdependent, but it is evidence of the theoretical power of this basic sociological concept that it could utilize the work of men as apparently far apart as Freud and Pavlov and make improvements upon both. Sociology, along with astronomy and many other sciences, is indebted to Euclid, Bacon, Maxwell, Bunsen, Mendelyev and thousands of others in many fields. The principle of organic cultural interaction and interdependence is well illustrated by the development of natural science and by all other institutionalized behavior.

Sociology has not directly influenced physical science as much as it has biology, but similar effects can be noted. Accumulating scientific knowledge of diverse cultures destroyed all types of extreme geographic, geologic and climatic determinism. The development of human geography has been mentioned. The greatest effect, however, is probably indirect. All physical problems are always aspects of the culture in which

the physical sciences exist. It is the solution of culturally determined practical problems which give rise to "pure" scientific questions. The technological and ideological changes thus brought about modify the culture which in turn modifies the theoretical and practical work of physical scientists. Thus, the reciprocal scientific interrelations between the cultural, biological and physical sciences, whether "practical" or "pure," can not be denied. It takes a specific kind of culture with a certain kind of implicit or explicit values to endow a Faraday or a Millikan. Showing the cultural origin and interaction of these values modifies them, and this in turn modifies the problems of the physical sciences as well as the means available for their solution.

Perhaps this organic interdependence of the cultural and physical sciences can be made clearer by considering the concept of relativity. Cultural relativity is much older than physical relativity, having been suggested by Xenophanes, more or less clearly expressed by Ibn Khaldun, and made explicit as a scientific principle by Comte. Comte's idea was still-born into a culture where the remnants of a metaphysical voluntarism were fighting a losing battle with the waxing cohorts of mechanistic determinism. During the latter half of the nineteenth century, social scientists made a futile effort to apply an oversimplified, unilinear evolutionary theory to societal phenomena. The more they learned about their data, however, the more futile the effort became. The result was the proliferation of atomistic monographic studies which introduced into the field of social investigation a kind of cultural relativity little short of theoretical anarchy. Any attempt to construct general theories by which the mounting monographic knowledge could be ordered and interpreted was flouted either as armchair philosophy or the metaphysical vamping of disordered minds. The crash of ambitious

⁸ Knight Dunlap, *SCIENTIFIC MONTHLY*, September, 1940, 221-225.

systems, constructed largely from speculative hunches rather than from empirical research, left a litter of verbal debris among which a few pariah theorists wandered all forlorn, muttering incomprehensible phrases to each other, or more often to themselves. Natural scientists in all fields ignored or jeered them; many of the theorists retaliated by a feckless rejection of all positivism, calling it mere planless empiricism, atomistic monographitis, pseudoscientific busy work. Some advocated a return to Plato and Aquinas. The old partially exorcised ghosts of medieval psychic entities began to walk again, and their fleshly advocates began to mutter in awed voices that "man is more than molecules," "mind is a great mystery," "there is *Something* more than energy," "you can't change human nature," "you can't predict human behavior." Being aided, no doubt, by extra-sensory perception, they began to hear again the flutter of mystical wings.

Many physical and biological scientists gladly accepted this point of view, and some still retain it even after most social scientists have wholly accepted the view that social phenomena are natural phenomena and the social sciences are natural sciences. Some eminent physicists still look for souls or spirits and assert that they find them; some eminent biologists still believe in mental telepathy, clairvoyance, souls and an innate moral sense; some assert that the social sciences are not, and because of the intrinsic nature of their data never can become, "real" sciences. It is difficult to understand how physical and biological scientists "get this way." An unkind guess might be that they have a vague childish fear that the prestige of their own fields somehow would suffer if they accepted the social sciences as legitimate rather than bastard. A kinder guess is their ignorance of the facts and methods of the social sciences and their general con-

tempt for the philosophy of science. Some of them are doubtless motivated by the unconscious desire to preserve the comfortable security of their folk attitudes and their traditional biases and prejudices in all matters social. Being compelled to challenge the folk knowledge that is inconsistent with the findings of their own sciences, they wish to be conventionally respectable in their social folklore and not be bothered by having to do any scientific thinking about societal phenomena. "Others they have disturbed, but they themselves they would not disturb."

When the concept of relativity was broached in physics, some scientists, even physicists, regarded it as final "scientific" proof that the ghost-makers and spirit-seekers were right; that the principle of causation was false; that prediction was impossible, even in physics; hence, it was folly to think one could predict in the much more complicated field of social phenomena. Radioactivity and subatomic physics strengthened these views. If you can not predict when, or how far, nor tell why, an electron will jump, is it not absurd to think you can tell what a human being will think or do, or when he will do it, to say nothing of why? It is needless to say Planck and Einstein never subscribed to such views.⁴ To say that such anarchy, indeterminism, "free will" or non-causality is proved by the "new physics" is not only nonsense, but "objectionable nonsense," as Einstein said (page 201 ff., *op. cit.*). Such ideas are figments of pseudo-scientific minds not yet entirely emancipated from Methodism, Aquinasism, Platonism and Unkulunkuluism.

Physical relativity is based upon a postulated absolute which seems to be a convenient if not necessary inference from empirical evidence. This is the

⁴ Max Planck, "Where Is Science Going?," New York, 1932. See especially the epilogue conversation between Einstein, Planck and James Murphey, 201-221.

fourfold time-space continuum.⁵ The absolute velocity of light, the assumption of knowable reality external to the knowers, the principles of conservation of energy and causality are also aspects of it. Needless to say, these absolutes are also imperatives for all cultural relativity. The failure to recognize this is responsible for what I have called anarchistic cultural relativity. When this is recognized, cultural relativity becomes consistent with predictive generalization and the statement of valid universal principles. Social phenomena are thus brought into the same frame of reference with all other natural phenomena. The real significance of physical relativity and the "new physics" is that they force us to recognize the organic interrelatedness of all natural phenomena. The closed systems of nineteenth century science are broken forever; all natural phenomena are a continuum; fixed and final entities are gone; the world is one of Becoming, not of Being; Flux replaces Finality; closed systems and all absolutes other than the derivative ones already mentioned, become methodological devices; there are no more "givens," but only "takens,"⁶ and the latter are meaningful only within their "taken" frames and their carefully stated limits; conservation of energy really means transformation of energy; simplistic causation gives way to the idea that all antecedent events are operative in each occurring event—the cause means the manipulable variable, or the immediate precursor of an observed object or action; all events are determined, but the universe and every contained segment of it are indeterminate, unfinished, changing; there is no "far-off divine event toward which the whole creation moves"—not even the entropy of Clausius, for as Arrhenius

pointed out long ago,⁷ if we assume an infinity of time, as we must, universal entropy would have been reached an infinity of years ago or an infinity of infinities ago. There is no such thing as creation; there is only *creating*, the incessant transformation of energy systems. The universe appears to run *up* as well as *down*; or more accurately, the energy dissipated in one system or segment is equal to the energy aggregated in other segmental systems; integration equals disintegration. This has long been observed in social systems, *e.g.*, when one culture or civilization "falls," another "rises," when one leader passes, another appears, etc. It might be called the principle of Societal Conservation, or Succession. It seems equally true of all biological and physical systems.

The result of these changes in the thoughtways of science is a growing theoretical consensus among all scientists. This has come about, not by social scientists accepting the crude mechanistic determinism and closed-system views of nineteenth century physicists and biologists, but because the latter have recognized that their data are similar in nature to social data. The principles of organic interaction of all natural phenomena and relativity have put unity into the universe and made possible and inevitable the all-encompassing unity of science. Even though it still shocks some animistic-minded persons, we see societal data rapidly being brought into the general framework of natural science. "This too, too solid earth" has melted: matter is energy; mass is mostly volume with relatively greater distances between the constituent units (nebulae, stars, molecules, atoms, electrons) than is the case with social masses and their

⁷ Svante Arrhenius, "Worlds in the Making," tr. H. Borns, 191 ff., New York, 1908. Entropy increases in stellar systems but decreases in nebular systems; the transformation of cosmic energy is reversible. Millikan has suggested the same thing in connection with cosmic rays.

⁵ Planck, *op. cit.*, 195-199.

⁶ John Dewey, "Logic, The Theory of Inquiry," New York, 1938, 124, 224, 522.

biophysical units (cultures, nations, groups, persons). Each electron must now be conceived as a unique variable with varying charges, positions, movements and relations to other electrons; I suppose the same would be true of the energy quanta themselves. Physical "constants," like those of biology and culture, are only conceptual constants, and can be treated as such only for certain purposes, in a specified set of relations, and within clearly defined limits. All the "constants" and "stable" factors in nature are so only within the "system" in which they are "taken"; all the predictions of science are probabilities; natural phenomena, even in the most severe experimental set-ups, never occur *exactly* in accordance with the conceptualized descriptions which are scientific "laws," "principles," hypotheses. A world in flux is a precarious, problematical world of constant energy transformations; the world of science is a world of constantly increasing approximations to accurate description of what is going on—and these descriptions must always be *relative*, must be "taken" in relation to something. In this kind of a world, persons are not so uniquely unique as many people still like to think. Every item of experience in the universe is unique with a uniqueness that varies from instant to instant. When physicists and biologists actually and vividly realize this, they are likely to have a greater fellow-feeling for social scientists.

No segmental system, and all systems are segmental, including Einstein's finite but unbounded universe, can be treated realistically as closed; methodologically, it can, and I think of necessity must be so treated, but this is merely a convenient scientific device which has been found highly useful. The incessant constructive and destructive changes within and between all (relatively) separate "taken" systems, including the entire

universe, which is also a "taken" system, render the concept of a closed system meaningless; this is also true of all "stabilities," "gestalten," "perdurable entities" and all fixed and final energy systems. While social scientists developed the concepts of organic interaction and relativity which have been found equally applicable to physical and biological reality, physicists and biologists have developed the best methods of dealing scientifically with such reality. Thus, the ontology of social science has converged with that of the physical and biological sciences, while the social sciences are rapidly taking over the epistemology and methodology of biology and physics. Physicists and biologists are now beginning to see that it is slightly silly to say "you can't change—or predict—human behavior" when it is becoming obvious that everything in nature can not do anything but change. It is also true that men have always predicted human behavior on a common-sense level, just as they have similarly predicted physical and biological behavior. Now it is beginning to be equally obvious that *scientific* prediction of human behavior is possible for the same reasons and by the same general methods that have made it possible to predict physical and biological occurrences.

Physicists and biologists are also beginning to realize that many social scientists are as conversant with natural science ideology and methodology as they themselves are. All natural scientists, including social scientists, are beginning to talk the same language. Ghosts, entelechies, emergent evolutions, "there is something *different* about man," "the mystery of life and mind," "the magical mindedness of the jungle, the mystical occultism of the medicine man and the priest, the personification and reification of abstractions, are now rapidly disappearing from the social sciences. The

great lurking places of these prescientific ideas, especially as they apply to social behavior, are the compartmentalized minds of some physicists, biologists, old-fashioned social "scientists," the scientifically illiterate minds of politicians, priests, artists, publicists, etc., and the untutored masses.

One effect upon many minds of the world picture above described is a loss of faith in natural science. The quest for certainty⁸ seems a hopeless quest and it has become fashionable in some quarters to sneer at science. There is a revival of the religion of the irrational, aided even by some scientists, *e.g.*, Lodge, Eddington, Carrel, McDougall, Rhine, etc.,⁹ the growth of Holiness religions, New Thought, divine healing, to say nothing of the economic and political big medicine of Communism, Nazism and private-profit Capitalism. The serious scientist, especially if he is a social scientist, who is critical of the current cults of his culture is suspect in all countries and is "concentrated" in many. This all-encompassing pressure of the irrational threatens the integrity of all scientists in all fields in all countries. There are none, or few, who entirely escape its distorting influence. Social scientists are probably more immune to it than physical and biological scientists because they know vastly more, though their *scientific* knowledge is still meager, about how and

why persons and groups behave as they do.

This brings us face to face with the scientific problems of sociology. Essentially, they are the same as those of all the natural sciences. The specialist in all fields is the inheritor of a more or less systematized body of facts and principles, a number of problems and a set of mental and physical techniques for solving them. Of course, all three of these factors are variables and subject to great temporal and spatial changes. All scientists have in common the generalized concept of the organic interaction and continuity of all natural phenomena and the consequent concept of relativity; they also have the highly developed natural science methodology; finally, they have the faith that scientific knowledge is "good" because in the long run it aids man in his struggle for survival and what we somewhat vaguely call the "good life." If a scientist lacks this faith, his work becomes mere puttering busywork or a petty racket. Another thing all scientists have in common is the frequently stated but unsound distinction between "pure" and "applied" science.¹⁰ The only real distinction I can see between them is their temporal orientation. The applied scientist wants usable results at once; the pure scientist is willing to wait, being sustained, perhaps, by a faith in the ultimate usefulness of all scientific knowledge. His immediate interest is the solution of the scientific problem; he believes it is worth solving because it sometime will be useful in solving man's practical life problems, one of the most insistent of which is his itch to *know*, to adjust himself to the kind of world he seems to be living in. There is considerable evidence that this scientific faith is justified by its results. Many practical applications of

⁸ John Dewey, "The Quest for Certainty," New York, 1929, especially 204-222 for the disturbing effects of the new science. The whole book is a discussion of the way out of uncertainty—which is the way of probability natural science. Cf. Chapter IX, "The Supremacy of Method." See also Part IV, "The Logic of Scientific Method," in "Logic," cited above.

⁹ They do not attempt to "prove religion" by science, as Eddington says in his reply to his critics ("New Pathways in Science," New York, 1938), but they make statements that have no scientific basis which give aid and comfort to the animistic folk mind of the masses. The prestige of their names becomes "proof" for all sorts of nonsense which uncritical minds want to believe.

¹⁰ John Dewey, "Experience and Nature," 162-165, New York, 1925, suggests that any science that is not applied, or applicable, is really "impure" or nonexistent.

what appeared to be the purest of pure science are quickly made; on the other hand, many revolutionary discoveries have been made as by-products of applied science, and the findings of practical, even "commercial," scientists and engineers are constantly adding to the cumulative body of "pure" sciences.¹¹

In sociology, the situation is the same. Practical problems, or social problems, give rise to sociological, *i.e.*, scientific, problems which may be called practical or applied sociology. Such research is reciprocally related to pure sociological research and may advance it as much as pure research may aid in the solution of social problems. A social problem may be defined roughly as behavior which is or is thought to be detrimental to the welfare or existence of the group. In Pareto's terms, it is probably a derivation from the residues of group persistence, sociality and equilibrium.¹² It is an aspect of the mores, or collective values, of the group. A social problem in one culture may be nonexistent in another culture or in the same culture at a different time. Scientists, or any other distinguishable class, may regard a certain type of behavior as a social problem, or a more serious one, than it is judged to be by the majority. For example, many Americans regard the adulteration of food as a more serious social problem than the adultery of spouses, though the great majority regards such an idea as shocking and absurd. The same may be said of bank robbing and bank wrecking; white-collar criminality and murder, rape, arson or kidnapping; excessive profits and excessive drinking; lack of proper sex education and prostitution; and so on. Social problems arise and disappear through changes in popula-

tion, natural resources, technology, science and institutional organization, which modify the folkways and mores.¹³

Sociological problems, whether pure or practical, are defined by the culture. Even when the scientific problem is "purest," that is, a nonutilitarian expression of the scientist's desire to *find out*, to order and/or understand his universe (*verstehende und ordnende Wissenschaft*), the scientist believes its solution will have ultimate use. However, most scientific problems are and should be practical, that is, relevant to immediate and pressing problems of personal and societal adjustment.¹⁴ There may be widely different opinions as to what are desirable adjustments; the application of scientific knowledge may produce results vastly different from what the scientist or the public expected; the long-run effects may be "detrimental" rather than "beneficial." On the whole, however, none of these things have been true, and the more specific the problems have been, the fewer have been the unexpected and undesired results. While all practical problems are functions of specific cultures, there are some which are almost universal, such as the desire for long life and good health, adequate food, shelter and clothing, more recreational and art facilities, improved transportation and communication, the control of crime, protection of persons and property, and in recent years, the extension of science and education as a means of implementing these objectives.

¹¹ I have discussed these inconsistencies in values in *Sociology and Social Research*, January-February, 1935, 266-276, and their relations to conflict and control in *American Journal of Sociology*, January, 1939, 499-509.

¹⁴ W. F. Ogburn in "Essays on Research in the Social Sciences," "Considerations in Choosing Problems of Research," 161-171, Brookings Institution, Washington, D. C., 1934. The whole volume is very useful. See also Robert S. Lynd, "Knowledge for What?," Princeton, 1939; also J. Dewey, *op. cit. supra*.

¹¹ Randolph T. Major, *SCIENTIFIC MONTHLY*, August, 1940, 155-164.

¹² V. Pareto, *op. cit.*, sections 991-1088 (persistence), 1113-1206 (sociality) and 1208-1331 (equilibrium).

Experience shows that "pure" science is of the greatest importance to the development of applied science. If pure science is neglected, or denied a free and wide-ranging opportunity to explore, the whole structure of science is threatened.¹⁵ Mere applied science, if there could be such a perversion of science, would soon result in scientific stagnation. As has been pointed out, the reciprocal interdependence of the "pure" and "applied" is so close that any discussion of their relative importance is impertinence. Both are indispensable and inevitable. In the case of sociology, the shortest road to scientific respectability and public prestige is emphasis upon practical problems such as prediction of marriage and parole success and failure, the prevention and cure of crime and juvenile delinquency, the Negro problem, population and health studies, etc. However, it is also obvious that the solution of many "pure" sociological problems such as the construction and refinement of appropriate instruments and techniques, analysis of the structuring and functioning of *plurels*, the definition and classification of societal phenomena, etc., is not only necessary for the solution of practical problems but is also a prerequisite for attaining the scientific respect of our physical and biological brethren. The reciprocal interdependence of pure and applied science is axiomatic.¹⁶

All natural science may be classified

¹⁵ Abraham Flexner, "The Usefulness of Useless Knowledge," *Harpers Magazine*, October, 1939, 544-552.

¹⁶ Lester F. Ward's first chapter in "Applied Sociology," New York, 1906, is still one of the best statements of this. John Dewey's views about the importance of choice is similar to Ward's position. Ward, like Comte, was more or less confused by the conflict between the mechanistic and voluntaristic points of view. A. N. Whitehead, Dewey and others have supplanted a philosophy which more or less resolves this conflict.

as either theoretical or empirical. One may do research in either field. Such research is as organically reciprocal as pure and applied research. The general pattern of empirical research is well defined in the physical and biological sciences and is rapidly being applied to research in the social sciences. It may be merely descriptive, classificatory or comparative; it may be qualitative or quantitative; ideally, it should be instrumental, quantitative and experimental. In any case, it must be based upon sensory experience which is public; that is, the data must be copious and accessible to any properly equipped person so that the research can be repeated. This is essential for verification, both of hypotheses and data. This is so elementary, it does not merit further discussion.

Theoretical sociology, however, merits a great deal of discussion—more than space permits. I have indicated above that it is and has long been in disrepute among empirical scientists. This is a good sign of the development of sociology into a natural science. The low estate of theoretical sociology is due to the fact that very few social theorists have properly conceived their function. By and large, they have been literary men or historians rather than scientific theorists. They have conceived their function as the rehashing of the verbal hash of ancient men of commonsense and insight who made some speculative remarks upon man the social animal, or man the masterpiece of the Almighty. They have resurrected many almost forgotten minor men and made scholarly reputations by citing hundreds of unknown names. They play games with each other over the relative merits of Polybius, Ibn Khaldun, Plato, Aquinas, Aristotle, Machiavelli, Montesquieu and Vico, to say nothing of men more recently dead, and they tend to accept or reject the results of empirical research in terms of whether or not their particu-

lar pet said, or, in the lingo, "adumbrated," it. It is remarkable what can be found in the works of these ancient worthies. There have been hundreds of doctoral dissertations in psychology and sociology, to say nothing of religion and literature and what have you, on Thomas Aquinas's Doctrine of This or That. The only thing comparable to what social theorists can find in the works of the worthies is what politicians can find in Washington's "Farewell Address," what judges can find in the Constitution and John Marshall's exegesis and *obiter dicta*, and what theologians have found in the Bible.

Social theory will continue in its present merited low estate until this bondage to the book, this modern scholasticism, is broken. A new breed of social theorists must arise in the land. If the ancients are studied at all, it should be chiefly to point out their ignorance and stupidity, not to worship and adore and take modern rabbits out of those funereal Black Hats; to show us how far we have come, not that we should return to these alleged founts of all wisdom. Social theory must become something more productive than antiquarian ardor, more creative than textual criticism and more stimulating than wordy rehashing of wordy hash. If this is what the sociological theorist has been and should not be, what would he be and do if he were a productive scientific worker?

He should have a sound training in the methods of physical, biological and cultural research and a wide knowledge of the findings and theoretical structure of these fields. He should be learned in the history of science and culture but should not be a historian. He should have some experience with empirical research. He should be literate in philosophy and mathematics and skilful in logic. Above all, he should possess a critical, creative, generalizing type of mind. His function should be to criticize, interpret

and systematize empirical research, particularly in relation to the findings of the other social sciences but also to those of physics and biology.¹⁷ He should be skilful at making explicit the implications of specific researches, pointing out deficiencies and suggesting remedies. He should be able to help the empirical researcher define his problems so as to give them the greatest possible scientific significance. He should be conscious of the gaps and weaknesses in the structure of the science and be fertile with suggestions for improvement. He should be an alert critic of theoretical statements and specific hypotheses that are incapable of empirical test, and aid in their restatement or final rejection. His business is to improve the accuracy and efficiency of the technical vocabulary of the science, but he must not confuse archaism and neologism with scientific terminology, verbal quibbles with substantive meanings, nor reifications with methodological abstractions. He should have a wide-ranging, well-stocked mind, which secretes useful hypotheses as the liver secretes bile. In short, he should be a well-trained natural scientist with the kind of daring, creative, factually disciplined imagination which sees relationships and implications that many careful routine researchers do not see. Most research is a routine technical matter, though it requires a high degree of specialized skill. It furnishes the cumulative knowledge out of which eventually come the synthesizing revolutionary generalizations of science. The theorist is an indispensable functionary in the

¹⁷ The kind of systematic social theory I am talking about is exemplified by G. A. Lundberg, "Foundations of Sociology," New York, 1939, and S. C. Dodd, "The Dimensions of Society," and a considerable amount of writing in the journals. This new social theory is not characterized by the fact that it is "sound" or "true," but by the fact that it is oriented toward the natural science conception of sociology. The test is not so much where it gets as the direction in which it is going.

institutionalized structure of science. In rare instances, we may find a great empirical researcher who also is a great theoretician, a Darwin, a Newton or possibly a Pasteur, but more frequently these specialized functions are not found in the same man. Maxwell, Einstein, Comte, Spencer, Ward, etc., were not particularly noted for empirical research.

There is grave need for this new type of social theorists. Such persons probably are partly born and partly made, but we have paid little attention either to finding or training them. The graduate students who specialize in "social theory" are still largely taught the history and exegesis of what is euphemistically called the sociological literature. Every department that trains many graduate students or does much research, and every large research project funded by foundations or government agencies, should employ one or more social theorists such as I have described. They should be especially valuable in the train-

ing of students, in the preliminary analysis of research about to be undertaken, and in the preparation of final reports.

Probably there is not a dozen such social theorists in the entire United States; certainly, not enough to staff the research and teaching we are doing. Most of our so-called social theorists have not yet accepted the simple proposition that social phenomena are natural phenomena and sociology is a natural science. If they have accepted it verbally, they have not realized its logical and research implications. Consequently, they still are wandering in the ancient wilderness of fuzzy words. Many empirical research men have accepted and are practicing this simple proposition—and they are producing scientific results. When the tradition of sociology as natural science is old enough and its cumulative scientific results are great enough, doubtless the Newtons, Daltons, Maxwells and Einsteins of sociology will appear.

ROYAL PATRONS OF SCIENCE

WITH the death of Ex-Kaiser Wilhelm II of Germany at Doorn in Holland, at the ripe old age of 82, a notable personality disappears from the arena of contemporary history. He will be viewed in various colors by posterity, but science will remember him as the main initiator and founder of the group of scientific research institutions in Germany known after his name. An account of the activities of these research institutes will be found in *Science and Culture*, Vol. 1, pp. 161, 175 and 332, 1935-36. These institutes were founded some time before the World War of 1914 and have been responsible for such epoch-making research works as the Haber process for synthesis of ammonia, production of synthetic rubber, new alloys, liquid fuel out of coal and lignite, etc. The Kaiser took personal interest in the foundation of these institutes, and secured funds from the state and industries.

In spite of the revolution of 1918, which overthrew the monarchy, the institutes rightly continued to be called after him. The Kaiser probably imbibed his appreciation of the importance of science to national life from his maternal grandfather, Prince-consort Albert, husband of Empress Victoria. The Prince was mainly responsible for encouragement of science in England about 1850. It was through his endeavors that the International Exhibition of 1851 was held at the Crystal Palace and the Victoria and Albert Scientific Museum was founded at South Kensington, and steps were also taken for the foundation of the Royal College of Science in London. The Prince was not much liked during his life time, but his services to England are being appreciated more and more as England is awakening to the importance of science in modern life.—*Science and Culture*, July, 1941.

SCIENTIFIC KNOWLEDGE IN HISTORICAL CRISES

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At the time of a great crisis, when organized society suffers from deep physical and emotional strains, the elements underlying human nature are revealed in their starkest and most poignant form. A terrible catastrophe tears away the cover of graces and conventions from civilization, disclosing the ignoble promptings of man as he stands alone in a fury of fear and brutality. The picture is not a pleasant one, for the lack is clearly shown of fundamental principles of justice and of the social considerations that civilization has built up.

Yet there are golden threads in the baser fabric. Human nature is not entirely selfish and panicky. Courage and generosity are ingrained in the superior types of men and women. The noble characteristics of idealism and chivalry are based on innate impulses of the human heart. Recent troubles in Europe have revealed these mixed promptings of man's nature, but Europe has seen worse crises than these.

Perhaps the most dreadful and spectacular of all afflictions that ever befell civilized society was the Black Death of the fourteenth century. This devastating epidemic ravaged Europe, Asia and part of Africa about 1348, and killed millions of people—in Europe perhaps a quarter or a third of the population. In many regions over half the people died within a few weeks, and the terrified survivors lived momentarily in fear of a similar end. Such a deadly scourge seemed like the end of the world to many dazed communities. They had never known anything like it and assumed

that it was a visitation sent from God or the Devil.

Hundreds of villages were entirely depopulated and deserted. The dead rotted in the streets; corpses clogged the rivers; the afflicted moaned without attendance or help. Families separated in terror when one or more members showed symptoms of the disease, and many were never able to find their loved ones again. Cattle and horses wandered in the fields unnoticed. Ships full of corpses coursed idly on the waterways with no one to steer them. A gripping fear fell over the civilized world; apparently God had forsaken His people.

Probably the deadly outbreak began in Asia, the traditional breeding place of disease. Famines and earthquakes, which left decaying corpses to poison the air and water, were at one time thought to be responsible. Actually rats and their fleas were the chief factor in its origin and spread. Modern theories as to the causes of an epidemic that took place before the discovery of America, when the science of medicine lagged and observers were generally too terrified to record data, are necessarily based somewhat upon conjecture and upon general knowledge of Asiatic epidemics as they have been studied in later years. The Black Death was a form of the bubonic plague, to which Europeans were unaccustomed at that time. To-day we guard against foreign rats, with their disease-laden fleas, especially at seaports.

The trading routes around the Black Sea were early affected, and from the markets of Constantinople the germs were diffused over Europe, partly by

overland travelers and partly by ships. The rapid spread and the extreme virulence indicated that it was an unfamiliar disease against which the constitution of man had aroused no resistance, for the human body has the faculty of building up counterworks against ailments to which it has had a chance to accustom itself. In this case there were no protection and no reserves. Medicine and health regulations gave no relief. What knowledge the physicians of the time possessed was helpless against the sweep of this swift messenger of death. We still have bubonic plague, but it is not so virulent, or else our bodies are less vulnerable. Perhaps we are healthier than our ancestors of six centuries ago, or at least better protected in sanitation and medical inspection.

The symptoms of the Black Death varied somewhat in the different localities, but had common likenesses. Inflamed boils and swellings appeared on the body, especially in the armpits and groin. The black spots, indicating dark blood or putrid decomposition of the flesh, were generally accompanied by spitting or vomiting of blood. The afflicted one died quickly, despite anything that could be done.

The Italian writer, Boccaccio, recorded that in Florence he saw two pigs pry around the clothing from a stricken man which had been thrown into the street. The pigs soon staggered as though poisoned and fell dead upon the infected rags. In some cities the streets were periodically cleared of corpses, which were piled in rows of thousands in pits outside the walls.

One of the most interesting aspects of the Black Death is the record of the measures taken by the medical men of the time to combat the disease. Such a study reveals vividly the state of science in the fourteenth century and throws light upon the subterfuges of the professional mind when it is pressed for results beyond its ability and knowledge.

The most celebrated medical organization in Europe was that at Paris, and naturally it was asked to formulate rules for resisting the dreadful plague that was ravaging Christendom. The doctors were required to be wise at command.

The reply of this medical faculty began gravely as follows: "We, the Members of the College of Physicians, of Paris, have after mature consideration and consultation on the present mortality, collected the advice of our old masters in the art, and intend to make known the causes of this pestilence, more clearly than could be done according to the rules and principles of astrology and natural science." This was a brave beginning, which shifted attention to the "old masters" and the faults of astrology. Rats were not even suspected, and fleas were too common to cause worry.

The document then went on to say that vapors, aroused by the heavenly bodies over India and the Great Sea, corrupted the water and air so that even fish died. Vapors were accused of carrying diseases as late as 1800. The fact that the sun was in the sign of Leo in the zodiac was considered an especially bad influence. In general, however, these learned professors believed that the constellations were striving to protect the human race and might succeed in breaking through the mist, thus converting it into "a stinking deleterious rain, whereby the air will be much purified." As soon as this rain began to fall, the people were warned to protect themselves by kindling large fires of green wood and not to go into the fields again until the earth was completely dry. Vapors, not rats, seemed to be the enemy.

Other learned directions promulgated by the organization were:

Poultry and water-fowl, young pork, old beef and fat meat, in general should not be eaten; but on the contrary, meat of a proper age, of a

warm and dry, but on no account of a heating and exciting nature. Broth should be taken, seasoned with ground pepper, ginger and cloves, especially by those who are accustomed to live temperately, and yet are choice in their diet. . . . Beet-root and other vegetables, whether eaten pickled or fresh, are hurtful; on the contrary, spicy pot-herbs, as sage or rosemary, are wholesome. Cold, moist, watery food is in general prejudicial. . . . Only small river-fish should be used. . . . Rain-water must not be employed in cooking, and every one should guard against exposure to wet weather. If it rains, a little fine molasses should be taken after dinner. . . . Olive oil as an article of food, is fatal.

The Parisian authorities warned against lettuce, but Southern doctors recommended it.

The admonitions about diet were conflicting and puzzling. If they were adopted at a conference, perhaps each physician insisted that his particular regulation should be included, so that as a consequence all the physicians were satisfied but the patients were overwhelmed and confused. If the physicians differed as radically then as now about diet, it is no wonder that the patients were mystified and gained little of value from the variegated directions. Perhaps these fourteenth-century physicians, knowing that they were up against a difficult problem, made their recommendations purposely vague and intricate, in order that, when no great benefit followed, they could ascribe the failure to the misinterpretation or neglect of some detailed rule. Such a device is not unknown even to-day.

On the subject of drinking, the group had this to say:

At breakfast, one should drink little; supper should be taken an hour before sunset, when more may be drunk than in the morning. Clear, light wine, mixed with a fifth or sixth part of water, should be used as a beverage. Dried or fresh fruits, with wine, are not injurious; but highly so without it. . . . Good clear wine should be selected and drunk often, but in small quantities, by day. . . . Equally injurious are fasting and excessive abstemiousness, anxiety of mind, anger and immoderate drinking. Young people, in autumn especially, must abstain from all

these things, if they do not wish to run a risk of dying of dysentery.

Although much of this advice about drinking is harmless enough, other items do not encourage confidence in readers who try to analyze what the doctors were aiming at. The author of the curious old book "Epidemics of the Middle Ages," Professor J. F. C. Hecker, M.D., of Frederick William's University of Berlin, suggested that this distinguished medical group at Paris

found themselves under the painful necessity of firing a point-blank shot of erudition at an enemy who enveloped himself in a dark mist, of the nature of which they had no conception. In concealing their ignorance by authoritative assertions, they suffered themselves, therefore, to be misled; and while endeavoring to appear to the world with eclat, only betrayed to the intelligent their lamentable weakness.

Such frankness from a fellow physician is commendable. Perhaps the fact that he wrote nearly five centuries afterward and that the medical faculty had been at Paris, rather than in his beloved Germany, prompted him to speak openly. If more members of the learned professions would speak up critically and pointedly about their mistakes and lack of knowledge, a tremendous amount of good would result. But they should not confine their criticisms to the members of the profession in foreign countries, and should speak up sooner than five centuries after the event.

Before leaving the subject of the recommendations by the doctors at Paris, it is interesting to quote their preventive precautions against the plague. For example:

Sleep in the day-time is detrimental; it should be taken at night until sunrise, or somewhat longer. . . . Going out at night, and even until three o'clock in the morning, is dangerous, on account of the dew. . . . Too much exercise is harmful. [Exercise caused excessive inhaling of the infected air, it was believed.] The body should be kept warmer than usual, and thus protected from moisture and cold. . . . Fat people should not sit in the sunshine. . . . Bathing is injurious. [Bathing opened the pores to

the air.] Men should preserve chastity as they value their lives. Every one should impress this on his recollection, but especially those who reside on the coast, or upon an island into which the noxious wind has penetrated.

Medical advice from other sources was not much better than that from Paris, for of course the condition of science in the fourteenth century did not permit of a very high level of erudition. A celebrated Italian authority of the time, Gentile of Foligno (follower of Peter of Abano), believed that much depended upon proper purification of the air. He recommended large fires of odoriferous wood both for the sick and the well, and directed the latter to wash themselves frequently with vinegar or wine, to sprinkle their dwellings with vinegar, and to inhale camphor and other volatile substances. This use of vinegar and wine as antiseptics was, of course, commendable. He favored powdered emerald taken internally, also liquefied gold—rather expensive medicines.

There were numerous attempts to treat the swellings or buboes when badly inflamed. They were burned with red-hot iron or gold, sucked by leeches or cut with knives. This last means proved best, for it let out the poison most expeditiously. Bleeding was a favorite remedy; the removal of five pounds of blood cooled the body, it was believed.

Many of the physicians of the time, as well as other authorities, ascribed the Black Death to the influence of the planets—a belief which went back, of course, to the earliest theories of magicians and astrologers. The grand conjunction of the three superior planets, Saturn, Jupiter and Mars, in the sign of Aquarius of the zodiac was thought to be particularly harmful; this conjunction was said to have happened definitely on March 24, 1345. There was much scanning of the heavens for signals from God and much debating among the learned as to the exact significance of the planetary movements.

The Jews, as usual, were accused of poisoning the wells and were horribly tortured and burned in great numbers, as many as two thousand at a time. Only a few Jewish children and attractive young women were ordinarily spared during these persecutions, although some of the others gained exemption by undergoing Christian baptism. In general, the dietary and sanitary habits of the Jews were superior to the prevailing ones, and thus made them suspiciously healthy.

For comparison of modern with medieval methods of fighting bubonic plague, a recent news-dispatch from China stated that science cooperated with superstition in the province of Fukien, where thousands were dying from this ancient affliction. The local officials started a campaign to eradicate the germ-carrying rats. Serum injections were given to all of the inhabitants who would submit to them, and infected cases were isolated. Educational posters were displayed to teach the people the cause of the plague and the best means of prevention. One poster showed a large picture of a rat with the inscription, "Where there are no rats, there is no plague." Another poster depicted a dead rat with fleas the size of eggs jumping from it to a live rat. From the live rat some of the fleas were shown transferring to a woman victim.

Along with these modern methods, many old superstitions still lingered among the Chinese people. Children wore pieces of dried marrow and other amulets on strings around their neck. On the doors of houses were hung scrolls inscribed with magic Chinese characters to charm away the disease. A popular theory was that the epidemic had been sent to the earth in a plague-boat dispatched through the air by evil spirits. To ward off this plague-boat, outdoor theatrical performances were held, and paper boats were ignited and launched into the air. In one district, terrified

peasants consulted the priests and were told that the year was a plague year. They decided to set the calendar ahead and start a new year with all the usual New Year festivities. Such superstitions are no more ridiculous than European beliefs in the fourteenth century. China is merely a few centuries behind the West in these curious ideas.

When Europe's accustomed ways of living were interrupted by the Black Death and terror stalked over the land, the regulations of society were relaxed and individual inhibitions fell away. Different personalities reacted in varied ways to such a condition. The vicious element of the community, always smouldering beneath the law-abiding surface, broke loose, and gangs of ruffians swarmed over the countryside, plundering homes and assaulting defenseless people.

Many normally sober persons, convinced that their last days were at hand, threw off restraints and resolved to get as much pleasure as possible amid the chaos around them. They roamed about, mocking at fate, drinking from tavern to tavern, and taking what they wanted from the private houses that were now more or less common property, since the owners had abandoned them or had barricaded themselves in upper rooms or in detached outhouses. It was a shameful spectacle.

As in every great crisis or calamity, many religious fanatics sprang into prominence and began prescribing their particular code of morals for others. Interpreting the plague as a punishment inflicted by God on a sinful world, they advocated austere living, with meager diet and abstinence from sexual intercourse. The more extreme went about in bands, whipping one another on their bare backs to convince God that they were thoroughly punished for their sins and had heeded His warning. Such bands of flagellants persisted for years

afterwards in their exhibitions, giving vent to the confirmed belief of the Middle Ages that a life of mortification of the flesh was a preparation for heaven and served as vicarious atonement in behalf of the aims of the community. Boys not yet in their teens joined these bands. Women embroidered banners for them. Revolting scenes of flogging and hysteria showed the decadence of the spirit. The world seemed to have gone mad!

Many religious-minded people were shocked by the schism in the Church of Rome and the decline in the dignity of the papacy—soon to fall into the spectacle of rival popes claiming the leadership of the Church. Conservative Christians were disturbed by the presence of the papal court at Avignon in southern France instead of the accustomed Rome. The old unity and supreme faith of the Middle Ages were disintegrated by this ecclesiastical unrest. The Black Death added to the confusion and helped to prepare the way for the Renaissance and the Reformation.

When desolation and devastation swept over Europe, many sensible persons withdrew to remote retreats in the country and lived as simply and as quietly as possible, taking along their relatives and friends when this was possible. There was in truth, little inducement to remain near the crowded centers of civilization, for anarchy had set in, and the authority of laws and the respect for human rights had broken down. Such a condition has a demoralizing effect on a community and destroys the incentive for decent people to live there. Recently certain areas in Europe have had similar experiences in the break-down of normal life.

As the Black Death became worse and infection grew more dangerous, physicians became afraid to attend the increasing numbers of sick, priests hesitated to go near them for administering

the last rites and grave-diggers threw the corpses into shallow pits or into the rivers—when they did not let them rot. The dogs ate many bodies, as food became scarce. Pope Clement the Sixth, from his seclusion at Avignon where he let no strangers approach him and kept protecting fires burning constantly, was obliged to consecrate the river Rhone so that bodies might be thrown into it without delay. "Charity was dead, and hope crushed," wrote the contemporary physician, Guy of Chauliac. All men fled from death. Avignon had been a center of gay life; it now went into mourning.

So great was the fear of infection that even a glance from the eye of a sufferer was believed to be sufficient to transmit the disease. This was in accordance with the ancient belief, inherited from pagan times, that in the process of vision, something material actually shoots out from the eye and touches what it sees. In the general confusion, frightened persons, hoping to buy immunity from contagion by gifts to God, hurried to the churches with gold and jewels. Often the priests, fearing contamination, closed the gates, whereupon the hysterical penitents threw their money and trinkets over the walls into the sanctified grounds. These were strange sights, but human nature was in terrible despair.

Many men who had lost their wives in the epidemic tried to become monks or priests, although a large proportion were illiterate. But monks and priests died as fast as the others, and some became panic-stricken and selfish. A great blow to the prestige of the Church and to organized authority in general was one of the direct results of this crisis.

In spite of the tightening of the morals of those who believed the plague to be a warning and punishment sent by God, and who were frightened into piety, a great relaxation of taboos and inhibitions followed the touch of such an upsetting infliction. Aristocratic and deli-

cate ladies allowed themselves to be attended by rough men, who formerly they scarcely knew existed, but on whom they now become dependent. Masters fraternized with servants, for the very good reason that they feared any one from outside. A great calamity brings equality in the face of danger. Something of the old chivalry and the distinctiveness of aristocracy were lost in this mixing of classes, even as a new spirit of human sympathy grew up when men and women saw that mutual helpfulness was necessary unless all pretensions to Christian principles and civilized society were to be abandoned.

The general effect of such an overturning of social barriers and the lessening of the customary consideration for aristocracy encouraged lawlessness and disorder, just as destructive wars emphasize materialistic advantages and bring reactions against idealism. For years afterward there were numerous disputes and quarrels over legacies, and the new shufflings of classes and individuals in a decimated society required much adjustment before friction died down. Selfishness and brute force had gradually to be subdued to permit a smooth working of the amenities of law and order.

The belief that the Black Death was sent by God to frighten a sinful world into piety and righteousness is not supported by what followed, for people generally were less moral and altruistic after the event than before. Such a severe shock, coming when medieval civilization was on the wane, shattered many decaying and outworn institutions and cleared the field for modern ways. For many decades in this chaotic period, however, God seemed to have forsaken His people. There appeared no end to the misery and degradation.

The rise in prices and the increase in wages which are usually ascribed to the Black Death have been exaggerated.

It did, however, bring discontent to large sections of the working classes, and it hastened the change from feudalism to a society dependent upon money and a commercial middle class—changes which had been slowly developing previously. Landlords tended to turn their farms into pastures for sheep when they found labor for cultivating the soil difficult to obtain. These economic changes marked the beginning of the serious labor problems which periodically disturbed later developments of western civilization.

The terrific strain of such a cataclysm as the Black Death left deep imprints on men's nerves and emotions for generations afterward. Any unusual manifestations of human peculiarities were attributed to repercussions of the effects of this dangerous visitation. One of the most curious weaknesses that afflicted the human race in the period after the Black Death was the dancing mania of the fourteenth and fifteenth centuries. This peculiar nervous disease appeared in Europe shortly after the plague had ravaged the land. A few fanatical individuals would begin a wild dance in the streets or the market place of a town, and the strange frenzy would spread to the spectators until perhaps several hundred people were dancing.

These affected victims would caper madly about, screaming and foaming at the mouth. Some would cry that they saw the heavens opening above them, and that Saint Peter or the Virgin Mary was visible there. Others had epileptic convulsions, and fell to the ground panting and senseless. Some of the victims died from injuries received during their paroxysms, and many suffered from fits of nervous trembling for long afterward.

At Aix-la-Chapelle in 1374, wandering troops of men and women were seen who had streamed out of Germany under the influence of this peculiar epidemic.

They formed circles, hand in hand, and danced in frenzied delirium until exhausted. Later the disease spread from Aix-la-Chapelle to other towns. Liege, Utrecht and Tongres were attacked. At Cologne more than five hundred people were possessed by the malady; at Metz eleven hundred dancers filled the streets. Peasants left their domestic duties to join the wild revels. Strassburg was visited by the mania in 1418. In Italy the delusion took the form of "tarantism," in which the victims imagined that they had been bitten by the tarantula, or they became excited at sight of some one who had apparently been bitten.

If only an occasional individual had become affected by such a nervous affliction, very little would have been heard of it. But the fact that the malady was contagious, and that hundreds of people at a time became possessed by it, made it a subject of deep concern. Why should masses of people have fallen into such a mental state that the sight of others capering about in a frantic ecstasy made them follow and do likewise? What disorder of the nerves could have been so prevalent that the streets became filled with temporarily insane people who apparently had to get a certain amount of dancing out of their systems? Why should staid peasants and respectable craftsmen have dropped their work and flung themselves about in such an abandoned manner?

Various explanations have been advanced for the curious epidemic. One theory is that brooding over religious problems at the end of the Middle Ages grew so pronounced that a reaction came in a sudden demand for violent physical outbursts. This theory is supported by the observation that many of the dancers had religious visions, and that several colonies of nuns were affected by the most extreme and perverted of the attacks. Another theory is that the repression and monotony of the saddened

life of Europe after the Black Death built up a condition of nerves that required an unconventional outlet.

Scientists have pointed out that human nature pursues periodic aberrations of strange and inexplicable courses. At intervals, fortunately not frequent, there appear evidences of peculiar states of mind that puzzle later historians. Wide-spread illusions occasionally spread over what we call the civilized world even to-day. Such an aberration was the witchcraft mania of the sixteenth and seventeenth centuries, and many of the wars of history now seem ridiculous and baseless. Some queer things have happened recently in Europe as a result of wars.

The inexplicable possibilities of human nature are almost endless, and man's capacity for irrational actions is astonishing. Dancing manias, witch hunts, and bloody wars over theological dogma or national vanity show the varied thoughtlessness of *homo sapiens*. Man can conquer his environment to an amazing degree by his inventions and scientific discoveries, but there remains his own unfathomable and unsatisfied nature that continues to puzzle wise sages. As Walter Lippmann recently said: "The human race is as yet only a little bit civilized and in time of serious trouble has a strong tendency to stampede back into barbarism."

Several other outstanding events of the Middle Ages are worth reviewing in order to show how blunders arise in civilized societies. Some of the great crises of historical times have, of course, been the decisive battles that determined what principles and what nations were to prevail. Many of these battles were dependent, not so much upon the bravery of the soldier or the strategy of the generals, as upon the invention of new weapons and the ingenious application of scientific principles. The conventional text-books do not always explain

properly the full effect upon history of these inventions and devices, as historians are sometimes lacking in understanding of science and engineering. The topic is a timely one, since modern innovations are revolutionizing warfare.

The tendency of the traditional types of human nature in such contests and battles has been to rely upon bravery and the sacrifice of soldiers. This was done during the early months of the World War, when each nation lost many of its finest men because of the old sentiment that to show caution was unmanly, and because of failure to realize that human breasts can not oppose machine-guns, high explosives and poison gas. Bravery, determination and perseverance—praiseworthy as they are and reliable for ordinary procedure—crumble to ineffectiveness against the cold might of science. Thousands of graves in France and Belgium testify to this truth.

The French people have at times been belittled by the Anglo-Saxons as frivolous and effeminate, probably because the influence of the centralized power of the French court permitted the cultivation of the graces and refinements of life far beyond what prevailed at the rough and insular English court. As a matter of fact, history shows that the French people have been the most gallant in Europe and have set many an example of courageous action under fearful strain and against withering odds. An episode from medieval history illustrates this too-dauntless reliance upon the bravery of their aristocracy, rather than on the inventive talents of their middle class, and demonstrates the havoc wrought by the rising power of applied science.

In 1346, several months before the Black Death decimated the two countries, Edward the Third of England invaded France with a few thousand men. If Philip the Sixth of France had

let the English wear themselves out, no great harm would have been done; but he proudly called out his nobles and a hired force of Italian crossbow-men. At Crécy, near Abbeville, the French forced a battle, employing the familiar tactics by which the feudal knights, clad in clumsy armor, rode their war-horses in shock formation at despised footmen.

But a new factor had come into warfare. The British archers, using great yew bows and arrows a yard long (cloth-yard arrows), had learned in battles against the Scots to shoot with remarkable power and deadly precision. The Italian crossbows were powerful but cumbersome and slow. All day long the French aristocracy charged with mad valor at the stubborn foot-soldiers but were mowed down by thousands in a terrible slaughter. The improved arrows from the strong long-bows penetrated even steel armor and were more dangerous than early types of muskets. The rows of French dead demonstrated that human courage could not compete with applied mechanics. This battle marked the rise of British military influence on the Continent.

But human nature learns slowly and forgets its lessons. Ten years later, when the Black Prince invaded the south of France and could marshal only eight thousand men, the French King John surrounded him with fifty thousand at Poitiers. If the French again had merely starved the British out, there would have been no great loss. But they wished to retrieve the laurels lost at Crécy, although again the French relied upon bravery and old-fashioned tactics. With incredible folly, the French knights charged up a narrow lane where the hedges on both sides were lined with British archers, who shot them down with ease. It was a worse disaster than at Crécy. The long-bows

were the machine-guns of their day, and were similarly under-estimated at first.

The French aristocracy were slow to learn the relentless danger of applied science, as represented by the force of a speeding arrow impinging on knightly armor. For generations, a fully equipped knight upon a horse had been a match for twenty untrained footmen. The French could not understand that this was no longer true. They made thicker armor, substituted plate for chain mail in a more complete covering of the body, and believed that they could rely upon dash and gallantry, not realizing that the heavier armor made the wearer more or less helpless from clumsiness, especially if he fell.

An ordinary man of to-day, though perhaps a little too tall for one of the medieval steel suits, would be liable to faint from the fatigue and heat of carrying it. The long-bow, by the way, was a Welsh invention; it was quick-firing but required unusual strength to manipulate. Many of the best archers were Welshmen. In 1414, the young English King Henry the Fifth—Shakespeare's engaging Prince Hal—landed in Normandy with fifteen thousand men. Once again the French could have cut his communications and tired the English out, but they had learned little in the two generations since Crécy. The mounted knight, pointing his long lance and charging splendidly ahead, was still their idea of war. With fifty thousand men, the French attacked Henry at Agincourt near Crécy, and the old story was repeated. The close formation of the French nobles, slipping upon wet ground, made quick movements impossible and offered easy targets for the British archers.

The battle ended in a massacre. Not until years later, when the French learned to develop the musket, did they

regain their old power in warfare. They clung to feudalism with a spirit of a better cause, just as human nature in thousands of similar cases has clung to obsolescent methods while science advanced and rewarded men ingenious enough to utilize it skilfully.

The cause of disastrous failures at many critical periods in the history of civilization has been the neglect of man to understand and use his scientific knowledge. Frequently, lesser lights in the crowd offered suggestions for improved methods and volunteered their talents but the slow-thinking officials, whom traditionalism had placed in command, often lacked the imagination to appreciate the new ideas. This procedure has been repeated time and again throughout the crises of history.

New ideas frequently have come from unconventional sources and were such disturbing factors to dignitaries in the established positions that much time was lost in adopting them. In the meantime, the original advocates of the new ideas were unrewarded and perhaps scorned for being different from their fellows. When necessity finally forced the adoption of the improved ways, the reluctant officials gradually began to think that the ideas were originally their own. Such has been the fate of many a poor inventor or gratuitous adviser who risked his future upon suggesting something new to superiors trained in the old ways. Similar procedure is not unknown in modern corporations.

Many of the advances in civilized life have been initiated by individuals of eccentric personality and disturbing views. At the beginning of their advocacy of the new ideas, their positions were usually vulnerable and perhaps their grasp of the subject imperfect. The officials who opposed them were often unintelligent men, representative of the institutions of a former day. Consequently, progress has been slow. The American philosopher William James, who was unappreciated on the faculty at Harvard until his reputation was established elsewhere, pointed out that the unorthodox but deserving thinker has a hard time at first. It should be the concern of the official leaders in a democracy to recognize and assist such struggling geniuses.

The appalling catastrophe of the Black Death, and of numerous military calamities due to inferior weapons, revealed the need for a better understanding of science. These disasters gave impetus to research and invention. Man resented his helplessness in situations where the elements turned against him. He saw the need to subdue nature by learning more about natural phenomena and the applications of science. Belatedly then the study of science was encouraged, rather than hindered. The modern world has profited enormously from this study. However, it has not yet learned how best to conduct such study, nor how to encourage the right types of scientists.

AMOS EATON (1776-1842)

SCIENTIST AND TEACHER OF SCIENCE

By Dr. H. G. GOOD

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At Williams College, from which he graduated in 1799, Amos Eaton showed particular interest in science and mathematics. He had lived on a farm in central New York and in his boyhood had acquired practical experience as a surveyor. All this was appropriate preparation for his life-work, which was the teaching of science and its applications to agriculture. Even while studying law in New York he sought out the scientists of that city, including such well-known men as David Hosack and Samuel L. Mitchill. A little later he conducted some botany classes, apparently in connection with an academy in the Catskills and was commended for taking his pupils into the field instead of teaching them from a book. After a disastrous experience as a lawyer and land speculator, and when he was already forty-one years old, he found his true vocation in science as an investigator, a text-book writer and an original and inventive teacher.

Further to prepare himself for his new career he studied at Yale College under Professors Silliman and Ives. He had access to Silliman's laboratory and to the large collection of minerals which the college had recently acquired from George Gibbs. It was Gibbs also who persuaded Silliman to establish the *American Journal of Science*, which is now in its one hundred and twenty-second year. Eli Ives was professor of botany and materia medica and a practicing physician. Eaton always cordially acknowledged his great obligations to the guidance and the life-long friendship of the Yale scientific group. In the spring of 1817 his real career began.

For several years after this period of study he carried out a series of geological surveys and gave courses of scientific lectures. His first course was delivered at Williams College and comprised lectures and field work in mineralogy, geology and botany. A contemporary witness wrote that "an uncontrollable enthusiasm for natural history took possession of every mind; and other departments of learning were, for a time, crowded out of the college." This course led immediately to Eaton's first important book, the "Manual of Botany," which, because no publisher would assume the risk, was issued "in a contracted form," 164 pages, by the students of the college. The first edition was immediately sold out and is now a very rare book. After this favorable beginning Eaton delivered many courses of scientific lectures in the towns of Massachusetts and central New York. The time was propitious. The academies were spreading and the American lyceum period was just opening. Science, when it was taught at all, was usually taught as a book subject and Eaton was among the first to study nature in the field.

Opportunity soon brought him back to his native state. Governor De Witt Clinton invited Eaton to deliver his lectures before the legislature and this brought him to the notice of Stephen Van Rensselaer. In this same year (1818) he published his "Index to the Geology of the Northern States." Van Rensselaer as a large land-owner was interested in geology as an aid to agriculture. With Van Rensselaer's support Eaton continued his geological surveys and

about 1825 he wrote: "My expenses have been defrayed for the past seven years by the Honorable Stephen Van Rensselaer who has expended more than eighteen thousand dollars during that period in causing researches and trials to be made for the purpose of improving and extending natural science."

SCIENTIFIC WRITINGS AND TEXT-BOOKS

Eaton wrote about twenty books, large and small, and about one hundred articles and items in journals and newspapers. Many of his science items were published in the *American Journal of Science*. Several of his books were intended for his own classes. One of these was the *Chemical Instructor* (1822). This was a laboratory manual and one of the early examples of its kind in any country. Although the directions which it gives seem rather indefinite it found considerable favor in the absence of better teaching instruments. A similar purpose guided him in the preparation of his "Zoological Text-Book" (1826), which was intended "for the Rensselaer School and the popular class-room."

Eaton's first schoolbook was a translation of the Botanical Dictionary of Louis Claude Richard to which he made some additions from other authors. In the same year (1817) his "Manual of Botany" appeared. This was revised, enlarged and re-issued every two or three years until 1840 when the eighth and last edition appeared. That edition described almost 6,000 species in about 600 closely printed pages. The Manual was in the main a Flora, that is, a key to classification with locations and, in the early editions up to the fourth, with notes on "the medicinal properties of each order." Gradually also he substituted a natural system of classification for the Linnean with which he had begun. Only the last edition contained any drawings or illus-

trations of any kind. It was the most complete manual of its day, "the field reference book for every botanical student in the northeastern United States"; and it continued in use until it was superseded by the works of Torrey, who had received his first botanical lessons from Eaton, and by those of Asa Gray.

In geology Eaton was an explorer but an explorer of a new and particular type; and it is on this work that his scientific reputation must rest. No such detailed examinations of large areas, no such "attempt at an orderly succession of the rock strata" had ever been made in America. By comparison, the surveys of Maclure, Schoolcraft and Edwin James were mere reconnaissances. It is made a matter of reproach to Eaton that he knew no paleontology, but he had little opportunity to learn, for no one in his circle knew any more. Paleontology was a new science in the early nineteenth century; but it must be admitted that Eaton did not seize the opportunity to learn when it came to him. The second edition of the "Index to the Geology of the Northern States" came out in 1820. It was wholly "written over anew, and published under the direction of the Troy Lyceum." In the preface, with the candor which was characteristic of him, he wrote: "It is but one year since any person residing in the interior of our district has had any *practical* knowledge of Organic Relics. A fortunate incident at length presented itself. The justly celebrated Le Sueur [C. A. Lesueur, 1778-1846], the friend and companion of Cuvier, was called to Albany. . . . I availed myself of his instruction for four weeks. Though my stock of knowledge in this department of nature is still very limited, I communicated all I knew to the members of the Troy Lyceum without delay." But he did not follow up this beginning and the first steps in the study of vertebrate paleontology in the United

States were taken by others. Eaton made his report on the geology of Albany County in 1820, that on Rensselaer County in 1822 and that on the Erie Canal strip in 1824. The Geological Text-Book did not appear until 1830. In all these he included some agricultural and economic information. Perhaps his patron, Van Rensselaer, must share the blame for Eaton's failure to follow up the newest and most important lead in geology; but Eaton, also, seems to have had a somewhat narrowly practical turn of mind.

This practical tendency was shown again in an elementary work on farm mathematics called a "Prodromus" of a Practical Treatise on the Mathematical Arts (1838, 192 p.). In the preface he remarked that he had published a similar small book under the title "Art without Science" as early as 1800 and again in 1830. Professor L. C. Karpinski has informed me that the Prodromus came out in a second edition in 1848. The book was perhaps a useful manual for farmers and artisans, but it was not mathematical in the scientific sense. The contents, and the preface perhaps still more, reveal an extraordinary lack of understanding of the true nature of mathematics and of its relation to the sciences.

The scientific work of Amos Eaton was practically completed in the ten years between 1816 and 1825. His exploratory work in geology added much to the knowledge of rocks and rock strata in the northeastern United States. Even the controversies into which he was ever ready to plunge were not without their use. He was one of the founders of the American Geological Society of 1819 which had Maclure for its president and which included Gibbs, Silliman, Dana, Parker Cleaveland, Chester Dewey, Samuel L. Mitchill and other well-known figures. Historians of American

geology are still debating whether Eaton should be called the "father" of their science. To botany he made few if any original contributions, but the laborious work of keeping his *Manual* up-to-date deserves generous recognition. To the other sciences upon which he wrote he contributed nothing new. He was much greater as a teacher than as an investigator and there he was great because his pupils went beyond him.

EATON AS A TEACHER

What Amos Eaton had accomplished before 1825 may be regarded as a preparation for the seventeen fruitful years which followed his appointment as senior professor of the Rensselaer School. His work has sometimes been compared with that of Liebig. Both had a laboratory in which the students themselves worked with materials and instruments, but there the analogy ends. Liebig prepared investigators in one science, chemistry, and Eaton, teachers of several sciences and of the applications of those sciences to agriculture and engineering. No scientific discoveries came from Eaton's laboratories. His students, even though many of them were college graduates, were mere beginners in science. His laboratories were arranged in four rooms, one for chemistry, a natural history room for geology, mineralogy, botany and zoology, an assay room and a fourth room for natural philosophy. This was the first laboratory or chain of laboratories in America in which numbers of students could carry out experiments at the same time. In Germany and Sweden and perhaps other countries the student laboratory was being introduced for instruction in chemistry; and a still earlier analogy is found in the pharmaceutical preparation rooms connected with medical schools.

The Rensselaer School differed from those European schools in that it was

intended to prepare teachers. And it was even more original in its methods than in its equipment. An early circular describes the methods as follows:

The most distinctive character in the plan of the school consists in giving the pupil the place of the teacher in all his exercises. From schools or colleges where the highest branches are taught to the common village schools, the teacher always improves *himself* more than he does his *pupils*. Being under the necessity of relying upon his own resources and of making every subject his own, he becomes an adept as a matter of necessity. Taking advantage of this principle, students of Rensselaer School learn by giving experimental and demonstrative lectures with experiments and specimens.

In every branch of learning the student begins with its practical application, and is introduced to a knowledge of elementary principles. . . . After visiting a bleaching-factory he returns to the laboratory and produces the chlorine gas and experiments upon it until he is familiar with all the elementary principles appertaining to that curious substance. [And so with tanning and other operations.] By this method a strong desire to study an elementary principle is excited by bringing his labors to a point where he perceives the necessity of it and its direct application to a useful purpose.

One should notice in this passage the narrowly practical purpose and, secondly, the direct training in teaching by having each student experiment and then lecture and demonstrate the results to his fellow-students. Professors also lectured to classes, and books were used, but the essence of the plan was in the student lecture and demonstration. There were exercises in land surveying, in construction and engineering work, in collecting and preserving specimens in botany, zoology and mineralogy, agricultural and gardening operations and experiments. These were made "the duties of students for a stated number of hours each day." Eaton's system was, therefore, a combination of the laboratory, seminar and project methods with a constant effort to develop skill in teaching. The Rensselaer School was one of our first schools for the preparation of teach-

ers. Its transformation into an engineering school was a later development.

How Eaton's work was regarded by an able judge of it may be seen in the estimate of one of his pupils, Professor E. N. Horsford of Harvard, who was a graduate of Rensselaer in the class of 1838. Horsford said:

It was a source of pride and satisfaction to me when, some years after my graduation, it was my fortune to enter Liebig's laboratory as a pupil, to find that the methods pursued under the guidance of that great teacher were in many respects the methods I had been familiar with in the Rensselaer Institute. . . . In a recent visit to Europe [1874] it was refreshing to see in the polytechnic education of Austria which now unquestionably has no superior in the world, the methods of the Rensselaer School of fifty years ago. It will not do to say that the methods were copied from ours, but it is proper to say that the inspiration that gave them to the eastern world moved the mind of Professor Eaton at a period as early as it did that of Pestalozzi, and Fellenberg, and Liebig, and under circumstances much less favorable.

DISTINGUISHED EARLY GRADUATES

The Rensselaer School attracted many able men as students and prepared many of them for distinguished careers in scientific investigation, teaching and popularization. The school was small in the early years, and the highest number of graduates in any one year during Eaton's headship (1825-1842) was eighteen, and the next highest, eleven. Before 1835, about one half of the graduates and one third of the non-graduates became lecturers, teachers and professors in colleges; in 1835 the school added an engineering course; and, after that, many of the graduates entered technical employments. The following table shows the occupations which attracted the largest numbers of the men who were graduated in the seventeen years of Eaton's connection with the school. Many of these followed more than one occupation in the several periods of their lives, and since each is counted only once it became

necessary to make a subjective assignment in some cases. The aim was to assign each man to the occupation in which he attained his greatest distinction. There were 166 graduates and they may be distributed as in the following:

TABLE OF OCCUPATIONS OF EARLY
RENSSELAER GRADUATES

Farmers, horticulturists	20
Scientists, professors and teachers of science	24
Manufacturers of scientific instruments	3
State Superintendent of Public Instruction	1
Director (Phila.) U. S. Mint	1
Professors (Theology, Sanskrit, Chinese, English)	4
Engineers	36
Physicians	18
Manufacturers (general)	19
Merchants	14
Attorneys	12

Of the rest, five were bankers, four clergymen, three insurance agents and two dentists, making in all one hundred and sixty-six.

Names will mean more than figures in this connection, because for the advancement of science and of education, leaders are more significant than numbers. The names of some of the following Eatonian graduates, classified as geologists, agriculturists, botanists and chemists, will be familiar to the reader:

(1) Ebenezer Emmons, class of 1826, who wrote extensively on geology. He started the Taconic controversy, but it is unfair to remember him for this alone.

(2) Douglass Houghton, 1829, state geologist of Michigan, professor at the University of Michigan.

(3) Robert Peter, 1829, chemist, serving in that capacity on the state geological surveys of Kentucky, Arkansas and Indiana. Peter secured the establishment of the Kentucky Geological Survey in 1854. Contributor to medical and agricultural chemistry. Editor of a farm paper.

(4) James Hall, 1832, successively state geologist of Iowa, Wisconsin and New York, was a great leader in the study of stratigraphy and invertebrate paleontology, and in the training of young geologists.

(5) Michael Tuomey, 1835, was state geologist of South Carolina, and later of Alabama, and professor at the University of Alabama.

The five named above were geologists. The following three were even more directly influential in the development of agriculture than the geologists. They are:

(6) George Hammell Cook, 1838, succeeded Eaton in 1842 as senior professor at Rensselaer School; but his most important work was done at Rutgers. He secured the Morrill Land-Grant for that institution and organized the New Jersey Agricultural Experiment Station, of which he became the first director.

(7) Asa Fitch, 1827, became state entomologist of New York in 1854, and this has been considered the beginning of economic entomology in the United States. He published many important studies, including some on the grain insects.

(8) Ezra S. Carr, 1838, was professor of chemistry and of agriculture at the University of Wisconsin. He also held professorships at the Rush Medical College, and the University of California. He prepared the way for the establishment of the California State Agricultural Experiment Station and finally served as superintendent of public instruction in that state.

The two of Eaton's pupils who were best known as botanists were:

(9) John Leonard Riddell, 1829, wrote a "Synopsis of the Flora of the Western States" (1835), which was the pioneer work on the plants of the Ohio basin. It was prepared while he was professor of botany at the Cincinnati Medical College. He acquired a reputation as a microscopist and was the inventor, in 1851, of a binocular microscope.

(10) Abram Sager, 1831, was the first professor of botany and zoology at the University of Michigan, and founded there the Sager Herbarium. Later, he became the head of the medical school at the same institution.

The well-known chemists who received their early chemical education under Eaton were J. C. Booth, E. N. Horsford and Robert Peter. Robert Peter has been included among the geologists, and might have been counted with the agriculturists, but was primarily a chemist, and a very able one. We may cite Booth and Horsford as follows:

(11) James Curtis Booth, 1831, had studied with Hare and graduated at the University of Pennsylvania before coming to Eaton; and after

a period of teaching near New York he worked with Wöhler and Magnus in Germany. He was the first American to apply the polariscope to the analysis of sugar. He filled many exacting technical and administrative positions and was as able as a teacher as he was as chemist, technologist and scientific adviser. He may have been, I think he was, the first to establish a student laboratory for teaching chemistry in an American public high school, the Central High School of Philadelphia.

(12) Eben Norton Horsford, 1838, studied with Liebig for two years, 1844-1846, and upon his return from Europe was appointed Rumford professor and lecturer on the applications of science to the useful arts, a title that would have delighted his old master, Eaton. He organized and equipped a student laboratory of analytical chemistry in the Lawrence Scientific School at a time when the chemistry students of Harvard College were still required to memorize a text-book. He published many experimental papers in Liebig's *Annalen* and in Silliman's *Journal*. In later life he became an industrial chemist and consultant and developed

a decided interest in the historical and archeological subjects.

If one had the space it would be easy to add to this list twelve or more other names of graduates who became distinguished in other, non-scientific, lines. There were a Sinologist, a lexicographer, a philologist, a medical missionary, a surgeon, several civil engineers, and others, among the one hundred and sixty-six graduates of Eaton's seventeen years at the Rensselaer School. Was it in the times, the men or the teacher that these became masters instead of underlings? Clearly all these were essential factors; and, therefore, it may not be necessary to undertake the impossible task of assessing exact values to each. Without Eaton American science education would have been less effective in that day and its history less inspiring now.

MAN IN GEOLOGICAL PERSPECTIVE

THE animal species that in the past have been able to maintain their existence for more than two or three million years are relatively few in number. Most of them were comparatively simple types belonging to the less highly organized branches or phyla of the animal kingdom. Many were inhabitants of the sea where environmental conditions were remarkably stable throughout long periods of time. Among placental mammals, the major subdivision of the vertebrates to which man belongs, there is no similar record of longevity. Except under extraordinary conditions of geologic isolation, no species of placental mammal has persisted more than two or three million years. No matter how successful it may have been temporarily in multiplying and spreading over the face of the earth, each has become extinct in a geologically brief span of time. Perhaps a half million years might appropriately be taken as average "life" of a species in this group of highly organized and notably complex creatures.

But extinction does not necessarily mean failure; it has frequently indicated the acme of achievement. For example, some of the now extinct three-toed horses and four-toed camels passed on "the torch of progress" to their descendants, the one-toed horses and two-toed camels, and thus gained long-continuing security for their kind.

What, then, does the future hold for mankind? The genus *Homo* has already existed for

three or four hundred thousand years; the species *Homo sapiens* has about fifty thousand years to its credit. If the average applies, we may expect nearly or quite a half million years more of existence for our kind and then either oblivion at the end of a blind alley or progressive development into some type of descendant better adjusted than we to the total environmental factors of the time.

But does the average apply? Must man exit from the scene through either of the doors—that which closed behind the dinosaurs and titanotheres or that which opened before the three-toed horses and notharctines?

Most animals tried to gain security for themselves by specializing in adjustment of structure and habit to particular environmental conditions, whereas man is a specialist in the adjustability of structures and habits to a variety of environments. No other vertebrate can live as can he, on Antarctic ice cap, in Amazonian jungle, beneath the surface of the sea or high in the air.

Furthermore, man is the world's foremost specialist in transforming environments to bring them within the range of his powers. Far more efficient than the beaver or the mound-building ant, he drains the swamp, irrigates the desert, tunnels the mountain, bridges the river, digs the canal, conditions the air in home, factory and office.—Kirtley F. Mather, *Sigma Xi Quarterly*, July, 1941.

INVASION OF A PROTECTED AREA BY EXOTIC PLANTS

By Dr. RICHARD M. BOND and ATWELL M. WALLACE

SOIL CONSERVATION SERVICE

PROFESSOR H. C. HANSON¹ stresses the value of areas that have never been cultivated or grazed, as checks with which to compare the effects of land use as practiced on surrounding lands.

During the course of a survey recently conducted by the Soil Conservation Service on the Pyramid Lake Indian Reservation, Nevada, such an "untouched" check area was examined and some interesting conditions were found.

The "check area" in question is Anaho Island in Pyramid Lake (See map, Fig. 1), an island of volcanic origin about 450 feet high. The elevation of the highest point is given as 4,360 feet on the U. S. Geological Survey, Reno quadrangle. Nearly all the rock outcrops are covered with several inches of calcareous tufa laid down by algae when the lake level was higher than it has been in historic times. The area of the whole island is approximately 260 acres. This may be divided into an upper section, of about 75 acres and a lower section of about 185 acres.

In the past there were two levels at which the water in Pyramid Lake stood long enough or often enough to form clearly marked beach lines. The lower of these marks the level of overflow from Pyramid Lake into Winnemucca Lake, and the other, a few feet higher, marks the overflow level of Winnemucca Lake into the Mud Lake Desert. On Anaho Island this upper beach line is best marked, and is considered as the demarkation between the upper and lower sections of the island. The upper section

has long been out of water, and there has been some weathering and soil formation on it. The lower part of the island shows almost no weathering; plant growth on this section dates only from about 1906, since which time the lake has fallen fairly steadily a distance of about 75 feet.

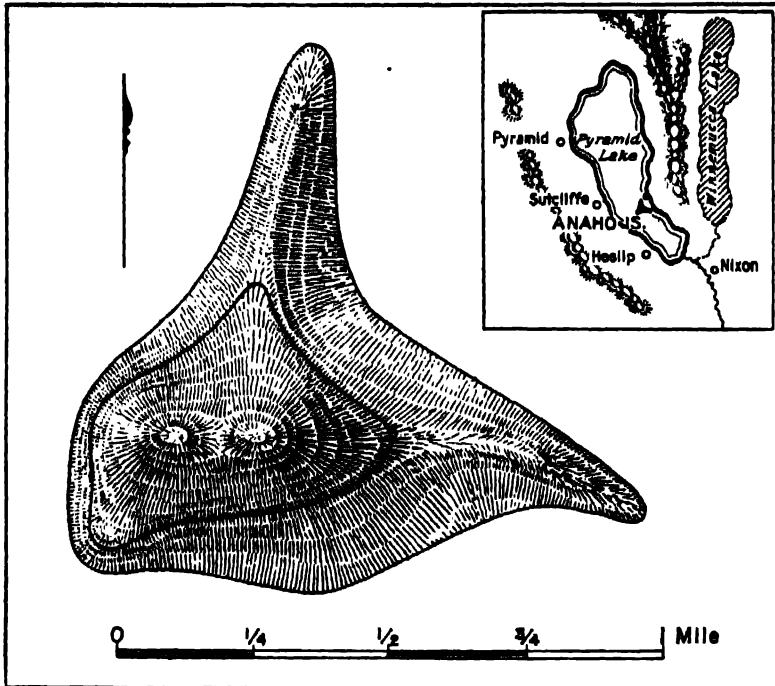
The vegetation of Anaho Island is generally characteristic of the lower, arid part of the Upper Sonoran Life Zone. There appears to be no zonal differentiation between the top and the base of the island. The reptiles are mostly Lower Sonoran, the birds are not zonally restricted, and the mammals have not been investigated.

As might be expected, the vegetation of the upper section of the island serves well as a check on the grazing use of the neighboring mainland. The main difference noted was that the perennial grasses *Stipa speciosa* and to a lesser extent *Poa* sp. were much more abundant and luxuriant than at comparable elevations on the mainland. It appears that grazing on the mainland has eliminated these grasses from the lowlands; they are still common in better watered areas, 1,000 feet or more above the lake.

The vegetation of the lower section of the island, where soil formation can scarcely be said to have begun, though characteristic of the same life zone, is very different and is limited to relatively few species. Probably less than one third of the sparse plant cover is native, consisting mainly of *Atriplex canescens*, *A. confertifolia*, *Sarcobatus vermiculatus* and *Distichlis stricta*.

The rest of the plant cover of the lower section of the island consists of exot-

¹ H. C. Hanson, THE SCIENTIFIC MONTHLY, 48: 130-146, 1939.



SKETCH MAP OF ANAHO ISLAND, PYRAMID LAKE, NEVADA

ics, mainly *Bassia hyssopifolia*, and the grasses *Bromus tectorum* and *B. rubens*; there is also a good deal of *Salsola kali* var. *tenuifolia*. That part of the lower section lying above the level of overflow into Winnemucca Lake has, in many places, also a good stand of *Erodium cicutarium*, probably because soil formation has progressed a little further here.

The exotic grasses and the *Erodium* have penetrated into many parts of the upper section of the island also. There they give the impression of having filled a vacant niche, without seriously competing with the native vegetation or disturbing it.

The following plant species are found on Anaho Island, Pyramid Lake. In the upper section of the island are found *Poa* sp., *Stipa speciosa* Trin. and Rupr., *Grayia spinosa* (Hook.) Moq., *Eurotia lanata* (Pursh) Moq. and *Sarcobatus baileyi* Cov. In the lower part of the island there are *Distichlis stricta* (Torr.)

Rydb., *Sarcobatus vermiculatus* (Hook.) Torr., *Bassia hyssopifolia* (Pall.) Kuntze, *Salsola kali* L. var. *tenuifolia* G. F. W. Mey, *Mentzelia albicaulis* Dougl. and *Oenothera caespitosa* Nutt. The species found on both the upper and lower sections include *Bromus tectorum* L., *B. rubens* L., *Sitanion hystrix* (Nutt.) J. G. Smith, *Oryzopsis hymenoides* (Roem. and Schult.) Ricker, *Atriplex confertifolia* (Torr. and Frem.) Wats., *Atriplex canescens* (Pursh) Nutt., *Erodium cicutarium* L'Her., *Lygodesmia spinosa* Nutt. and *Artemisia spinescens* Eat. This list contains only the species that were common or conspicuous in June, 1940. Many early-blooming, rare and inconspicuous species were undoubtedly overlooked.

Two subjects for speculation arise with respect to the vegetation of Anaho Island: 1. How did the exotic plants reach it in the first place? 2. How do they manage to survive there in competition with the native vegetation?

The answer to the first question is not very far to seek. Seed may have arrived by any or all of three methods from the mainland where all the species are common. They may have been carried by birds, carried by the wind or floated across on the water. The last seems most probable. Whether the seeds reached the island by wind or water, it is quite likely that the birds have aided in their local distribution.

The answer to the second question is more difficult. It would at first sight appear that suitable native primary weed species would be present, and at least as capable as the exotics of starting the plant succession. This seems likely because Anaho Island is a breeding ground for several thousand white pelicans (*Pelecanus erythrorhynchos* Gmelin),² which nest on the ground in dense colonies. They disturb the soil, and much of the vegetation is killed either by being trampled or through "burning" by the excrement of the birds. Since this disturbance caused by the pelicans has been going on for hundreds if not thousands of years, and since the colonies are often moved from year to year, it would appear that conditions on parts of the island should have been ideal for the continued existence of a stock of pioneer native plant species which would have

invaded the lower section of the island as it was uncovered by the receding water. This, however, does not appear to have happened. Nesting sites deserted for two or three years were found to support little but *Atriplex confertifolia* and the two species of *Bromus*. The following alternatives suggest themselves as possible explanations for these conditions:

1. The pelicans did not disturb the upper part of the island enough to encourage pioneer growth. By the time the lower part of the island was uncovered, exotics had largely displaced natives on the mainland through grazing and overgrazing, and these provided the only source of seed of suitable plants for the lower section of the island.

2. The exotic plants are more aggressive and have displaced the native species in competition.

3. The exotic species are intrinsically lower in the scale of succession than any available native plants. Perhaps they will in time be succeeded by natives when they have sufficiently affected the environment.

We wish to express our thanks to the personnel of the Vegetative Type Map Herbarium of the California Forest and Range Experiment Station, and to Dr. H. L. Mason, of the University of California Herbarium, for help in plant identification.

¹ E. R. Hall, *Condor*, 27: 147-160, 1925.

² R. M. Bond, *Condor*, 42(5): 246-250, 1940.

BOOKS ON SCIENCE FOR LAYMEN

INSTINCT AND ANIMAL BEHAVIOR¹

IN all accounts of the activities of animals, the great stumbling block on which explanations and theories either crash or build is that section of our ignorance which we hide under the term "instinct." Therefore, any attempt to examine animal behavior that does not involve instinct is like a ray of hope, no matter how uniformly disappointing such rays have been in the past. It may be said at the outset that the present book is one more addition to the long list of disappointments. The author states his aim is, "... to investigate the animal world and to study animals as creatures which feel and act as individuals. We shall see that all theories of mysterious mechanism, by which organisms are set in motion like machines, will disappear. Both animals and human beings will be seen to act according to one and the same fundamental principle—a psychological stimulus leads to a search for the *means* and activates the *will* to satisfy it."

When we come to read the body of the book, we are forced to the conclusion that what the author has been fighting against is not the usual conception of instinct, but a very naive one of instinct as a suddenly appearing, mysterious, almost unimaginable driving and guiding force. Against this generally discarded notion, he builds up a series of "impulses" and even titles the four sections of the book—Impulses of Self Preservation, Impulses Leading to Propagation, Social Impulses and Impulses of Migration. However, his "impulses" are very hard to distinguish from what most of us call "instincts." He attempts to differentiate the two by stating that an impulse "... has nothing whatever to do with

¹ *Animal Behavior*. J. A. Looser. x + 178 pp. \$2.00. 1940. Macmillan Company.

the idea of instinct. An impulse is not an established characteristic, but only a temporary biological expression for a psychological sensation to be determined later." The usual concept of instinctive behavior involves stimuli for its expression in any given instance. Thus, instincts of self-preservation are not manifest except when needed, *i.e.*, when some stimulus calls them into operation. Possibly "impulse," as a word, may be thought an improvement over "instinct," but as a concept, it is about the same. In the section of the book dealing with impulses of migration, the author's case becomes very weak. Indeed, all through the work, one finds evidences of too much "arm chair" natural history, some of it wrong, some of it over-simplified for convenient pigeon-holing. Much of it is acceptable, but is not infrequently marred by evidences of the author's unfamiliarity with the material, although this may, to some extent, be due to poor translation from the original German manuscript.

The book is illustrated by a good number (41) of black and white ink drawings by Erna Pinner and has a short, explanatory and rather cautious foreword by L. J. F. Brimble.

HERBERT FRIEDMANN

PSYCHIATRY AND THE SOCIAL WORKER¹

A GREAT amount of time and study have gone into the preparation and writing of this book—an expenditure of effort which has been going on for ten years or more in the American Association of Psychiatric Social Workers in an effort to define their field and function—and one is left with the feeling that these still are not defined, though the book does

¹ *Psychiatric Social Work*. L. M. French. xvi + 344 pp. \$2.25. 1940. Commonwealth Fund.

point up the trends within the entire field and the problems of definition.

A picture is revealed of the origin and development of psychiatric social work and of the A.A.P.S.W. as a specialized group with a professional function in the beginning but with this professional function becoming increasingly obscure as psychiatric knowledge, skills and techniques became more and more a part of social case work in general and of the professional training for all case work. It describes how members of the association went into all fields of work—first as consultants or as educators in mental hygiene—later as regular members of the case work staffs until since 1937 about 50 per cent. of the membership are so employed (about 25 per cent. in the family welfare field) and only about 50 per cent. remain in the hospital and clinic field with a marked tendency for association members and graduates of professional schools to reject this field for the other fields of case work.

All interpretation in the book is based upon the thesis that psychiatric social work is social work practiced in connection with psychiatry. It is, therefore, not an expression of the opinion of the association as a whole. It is the opinion of one group—the study having been made and the book written by early members of the association. The statistical study which covered number of workers, types of agencies represented, turnover among workers, professional equipment, salaries and opportunities for placement gave no opportunity for differences of opinion to be tabulated.

Interpretation often implies considerable question about the development of specialized skills that have developed and are continuing to develop particularly within the family and child welfare fields because these are not being practiced in connection with psychiatry

(mention is made that psychiatrists or analysts may be on the staff of the agency but this does not make it psychiatric social work). This feeling is not shared by the entire association.

That the book brings into focus important problems for the association is certain; that it has contributed to clarification of a definition of psychiatric social work is doubtful. With as general acceptance as there has been of the psychiatric social worker doing what has been considered psychiatric social work in a variety of agencies for a period of more than ten years, can the association (or a part of it) now say this is not psychiatric social work and make it so? On the other hand the association, which has been losing its identity, may need to renew its life, under this or another name, by defining its functions and activities in relation to psychiatry in the hospitals and clinics and thereby maintain a specialized service within the case work field.

DOROTHY THOMAS

FACT AND FANCY IN GENETICS¹

THIS new text-book begins with a chapter of historical matter, "The Rise of Genetics," well illustrated and fuller than is to be found in other texts currently in use. This favorable beginning is completely belied by the sequel. Chapter II deals with "The Laws of Mendel," commencing with a complete dose of genetic terminology defined in a way neither Mendel nor any other geneticist would comprehend. Samples: "The offspring of an experimental cross are *hybrids*. Breeding a hybrid to a brother or sister type is *inbreeding*." "If the hybrids in any generation resemble each other in all somatic characters, they are *phenotypes*. Phenotypes known to have identical factors in the

¹ *Principles of Genetics*. E. Grace White, 430 pp. \$2.50, 1940, C. V. Mosby Company.

genes are *genotypes*." Passing on to the discussion of the effect of external conditions upon character expression, we are surprised to learn that Himalayan rabbits from which patches of white and black fur are removed and which are then kept in a cold place will grow black fur where there was formerly white, and white fur where there was previously black (p. 46). Passing by numerous other inaccuracies and inadequacies of expression, we find, in Chapter III, "The Cytologic Basis," figures of mitosis from the author's previous "Text-book of General Biology" that show chromatids at metaphase quite un-oriented and chromosomes at late telophase still completely condensed, while the accompanying discussion describes a single spireme thread in prophase. As to chromosome number, "a change in chromosome number constitutes a species change" (p. 64). The section on "Meiosis" begins with the ambiguous sentence: "The meiotic phase may occur at three different periods in the life cycle; consequently, there are three different types or organisms" and leads us on to "threads (that) come to lie side by side in pairs which unite forming a thicker thread called the *pachytene*" (p. 68). Later "the chromatids move apart in pairs as they shorten and thicken, and assume shapes . . . (that) are believed to be caused by an interchange between sections of sister chromatids, and are called *chiasmata*" (p. 69). These misleading statements are characteristic of the author's style throughout.

The reviewer was unable to advance any farther in this hodge-podge of ill-

mixed fact and fancy. To imagine its effect upon an unsuspecting student would be enough to drive most teachers of genetics to frenzy.

H. BENTLEY GLASS

THE TELEPHONE IN A CHANGING WORLD¹

In the foreword by Marion Dilts to her most recent book, "The Telephone in a Changing World," there is a minor point of veracity. After explaining her inspiration in remarks by Sir Richard Gregory, she says that those with whom she discussed the idea were encouraging. The present reviewer at that time was even discouraging. He was appalled by the magnitude of the task which the young lady proposed: a Baconian survey of an industry three times her own age. In spite of the discouraging advice, she went ahead and completed her task.

The result is beguilingly readable although encyclopedic in range. It is not a source book but amazing in the variety and coverage of its sources. Not always would this reviewer have selected for emphasis the same items, scientific, social or economic. Selection and emphasis, however, are an author's privilege; and with the picture which results there can be no serious quarrel. The publishers would probably be safe to advertise the book on a money-back guarantee to purchasers who are not struck by at least ten pertinent facts outside their previous knowledge of the telephone. ¶On glancing through the book again I'll raise the publisher's ante to 20.

JOHN MILLS

¹ *The Telephone in a Changing World*. M. M. Dilts. Illustrated. xiv + 219 pp. \$2.50. April, 1941. Longmans, Green and Company.



THE PRESENTATION OF THE THEOBALD SMITH AWARD
DR. IRVING LANGMUIR, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF
SCIENCE, WITH THE RECIPIENT DR. HERALD R. COX, PRINCIPAL BACTERIOLOGIST IN THE UNITED
STATES PUBLIC HEALTH SERVICE.

THE PROGRESS OF SCIENCE

THE THEOBALD SMITH AWARD TO DR. HERALD R. COX

THE American Association for the Advancement of Science has two annual prizes. The first of these is the Thousand Dollar Prize for a paper of outstanding importance presented at each annual meeting. This prize was established by an anonymous friend of the association and has been awarded each year since 1923. The second prize is one thousand dollars and a bronze medal awarded at summer meetings for a distinguished contribution to medical science by a person under thirty-five years of age. The fourth award of this prize, which was established by the Eli Lilly Company, was conferred on Dr. Herald R. Cox at the meeting of the association which was held at the University of Chicago, from September 22 to September 27.

Dr. Cox received the Theobald Smith Award for his development of methods of producing vaccines for Rocky Mountain fever and related severe maladies known as rickettsial diseases, the causative agents of which are viruses. These diseases are called rickettsial by specialists in the field, in memory of Dr. Howard Ricketts, who first established the cause of Rocky Mountain spotted fever. At the time of the discovery Dr. Ricketts was a rising young scientist in the University of Chicago, for whom a bright future was predicted by all his older colleagues. But these predictions were not to be fulfilled because he lost his life from an accidental infection while he was studying the disease in Mexico City in 1910. With his death medical science added another bright name to its long list of martyrs who have made the supreme sacrifice in response to the simple call of duty.

At the Chicago meeting, Dr. Cox delivered a lecture before the Section on

Medical Sciences on "Cultivation of Rickettsiae of Rocky Mountain Spotted Fever, Typhus and Q Fever Groups in the Embryonic Tissues of Developing Chicks." Although the low forms of life that produce these dreaded diseases can not be cultivated successfully in the usual culture media, Dr. Cox found that they can be grown in the fertilized embryos of the eggs of hens. His results are not only of scientific interest, but they are of the highest practical value because they can be used for producing curative vaccines in large quantities and at relatively low cost. It is fortunate that Dr. Cox has perfected his production methods at the present time because the Dakotas and neighboring regions have been suffering from the severest known epidemic of sleeping sickness, one of the diseases belonging to the rickettsiae group. In fact, the situation was so serious that Dr. Cox hastened back to his work in the Rocky Mountain Laboratory of the U. S. Public Health Service, Hamilton, Montana, cutting short a visit to his former home in Rosedale, Indiana.

There are several interesting aspects of the award to Dr. Cox and of the work for which it has been given. Foremost is the fact that he perfected his methods just before a severe epidemic of a rickettsial disease. Then, it must be encouraging to every student in medical science to learn that a young man only thirty-four years of age has been able to make such a distinguished contribution to human welfare and that his work has been so conspicuously honored. It is encouraging that such a prize as the Theobald Smith Award has been established, for it honors the memory of a great scientist and rewards those who follow successfully in his footsteps. Finally, it is

inspiring to all of us that from such villages as Rosedale young men emerge with the self-reliance, industry, intellectual integrity and persevering ability neces-

sary to achieve distinction in the morning of life, for these are the men in whose hands the future of our civilization rests.

F. R. MOULTON

THE GREAT GEOMAGNETIC STORM OF SEPTEMBER 18-19, 1941

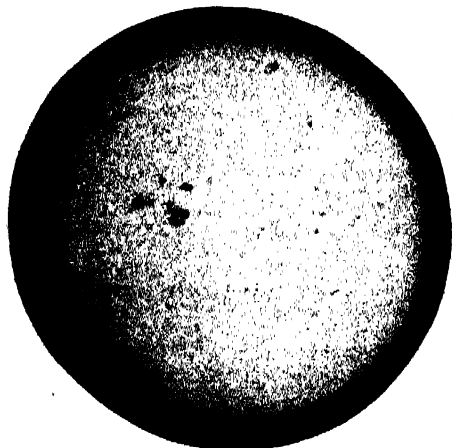
NEARLY matching in violence the great geomagnetic storm of Easter Sunday, March 24, 1940, the second greatest geomagnetic storm of the present cycle of solar and geomagnetic activity occurred on September 18, 1941. When the records have been completely reduced these two storms, together with several others of unusual violence, will probably mark the current cycle as the most active in the annals of geomagnetism.

The recent storm was noteworthy for two reasons—it was accompanied by one of the most prolonged and intense auroral displays ever observed in the eastern and mid-central parts of the United States, and its occurrence was expected, even predicted, on the basis of known relationships between solar and magnetic activity. However, the violence of the storm and the magnificence of the auroral display exceeded both prediction and expectation.

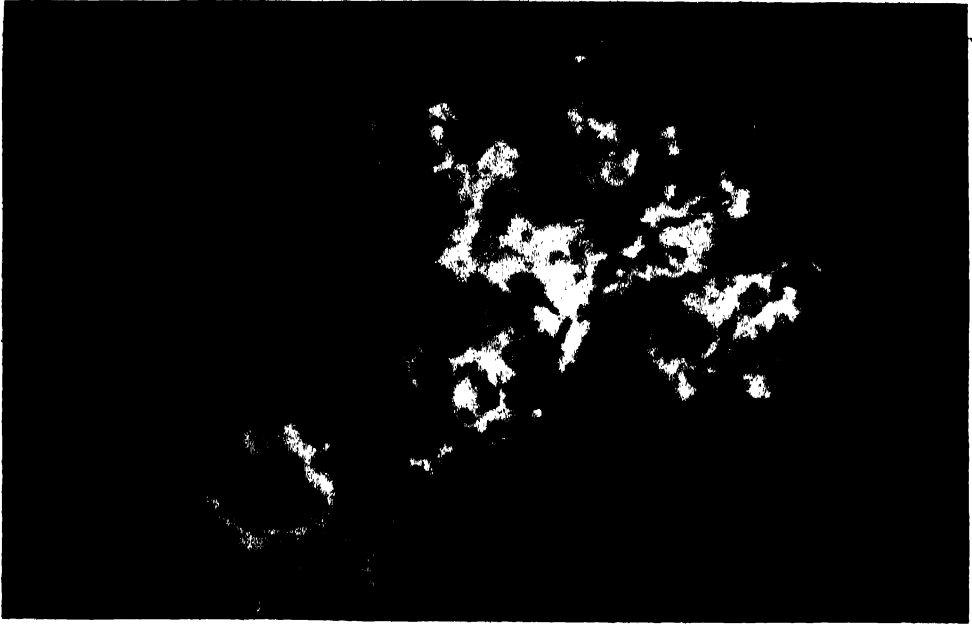
Those who have watched the develop-

ment of sunspots in relation to geomagnetic activity recognize that, while no direct and infallible relationships between solar and geomagnetic activity have yet been discerned, large and rapidly changing sunspot-groups are most frequently associated with geomagnetic storms, and that the efficiency of these spot-groups in producing terrestrial effects appears to attain its maximum when the groups are in low heliographic latitudes and passing the central meridian of the sun. H. W. Wells, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, has closely followed the daily reports of areas, numbers and locations of sunspot-groups supplied to the Department by the United States Naval Observatory. Several days before the occurrence of the recent geomagnetic storm he formally warned that radio people should be watchful for disturbed geomagnetic and ionospheric conditions beginning about September 18. The importance of this warning has been well demonstrated by what followed.

For several days the earth's magnetic field had been slightly disturbed. At 11 P.M., EST, September 17, violent fluctuations in the direction and intensity of the earth's magnetism began, increasing in severity for the next few hours, attaining a maximum of activity, according to the magnetic records, between 1 P.M. and 3 P.M., September 18. During this interval—more precisely from 2:45 P.M. to 2:50 P.M.—vibrations in electrical power transformers at Takoma Park (Maryland) and at Safe Harbor (Pennsylvania) were noted and a variation of one per cent. in voltage was recorded. These



THE GROUP OF SUNSPOTS
NEARLY 100,000 MILES IN DIAMETER, PHOTOGRAPHED IN NORMAL LIGHT ON SEPTEMBER 15 BY THE MOUNT WILSON OBSERVATORY.



THE GREAT SUNSPOT GROUP

PHOTOGRAPHED WITH LIGHT FROM OVERLYING CLOUDS OF LUMINOUS CALCIUM VAPOR, SEPTEMBER 16, 6:36 A.M., PACIFIC STANDARD TIME.

transformers are at the termini of a 230-kilovolt interconnecting line extending approximately 100 miles from Washington, D. C., to Safe Harbor, Pennsylvania. Meanwhile extensive interference with long-distance radio, telegraphic and telephonic communications was being experienced.

But nature had scheduled her choice act for the evening hours. Those who watched the evening sun go down were aware of a strangely persistent glow in the northwestern sky. As the sky darkened, distinct rays were visible in the northern sky, brightening, fading and continually changing. By 8 P.M. the entire sky was filled with rays apparently converging to a point near the zenith to produce a vivid coronal formation. Various forms of auroral activity, rays, curtains, extensive arcs and flickering rays resembling search-light or air-beacon beams continued until almost dawn September 19. Some auroral activity was noted during the preceding and

following nights, neither being comparable with the display of September 18-19.

The coronal display was visible simultaneously in widely separated parts of the country. To all observers everywhere the rays seemed to converge toward a point slightly south of the zenith. Actually, of course, there was no convergence. The particles shot off from the sun, being electrically charged, can not freely cross the earth's magnetic field and must travel in the direction of the magnetic lines of force. At Washington the lines of force are tilted about 20° southward from the vertical while further north the tilt is less. Thus all observers were viewing a bundle of closely parallel rays, extending tens or hundreds of miles upward in the rarefied atmosphere, and appearing to converge toward what is called the magnetic zenith just as railroad tracks appear to converge toward a point on the horizon.

At the time of the most outstanding part of the display vibrations in electric

power transformers were again noted and voltage fluctuations of two and one half per cent. were recorded in Baltimore. According to a report of R. N. Weaver, chief operator of the Safe Harbor Water Power Corporation, one of the operators, R. S. Mellinger, observed that vibrations in a transformer "could be very definitely tied in with the aurora-borealis display, in that the vibrations would build up in intensity with the build-up of brilliancy of the lights."

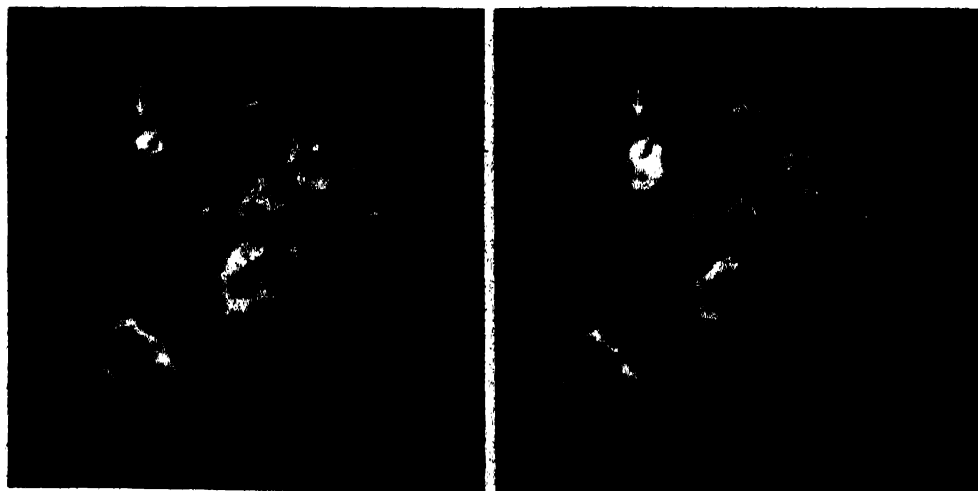
The immediate cause of the effects on electric-power systems and wired communication lines is well understood by scientists. Rapid changes in the earth's magnetism occurring during the storm induce electric currents in the conducting substance of the earth (of which the power- and communication-lines are a part) in very much the same manner as electric currents are generated in the armature of a dynamo. These currents overload the lines and produce the effects noted.

The magnetic changes in turn are produced by intense electric currents—amounting to millions of amperes—flowing in the high atmosphere brought into

existence in some as yet unexplained way by the influx of solar particles which produce the auroral effects. Thus when one gazes at an apparently quiescent auroral arc he should realize that the luminous belt he sees is in reality the path of an exceedingly intense electric current.

Disturbances of radio communication associated with geomagnetic storms are also explained by the high atmospheric effects of the storm. Radio communication over long distances depends upon reflection of the radio waves by relatively sharply defined strata in the high atmosphere. Bombardment of these high regions by solar particles disturbs the homogeneity of the layers with resultant scattering and absorption of the radio waves.

Some curiosity may arise over the fact that this very exceptional storm occurred considerably after the passage of the maximum of the present sunspot-cycle which may be taken as in 1937. This is not remarkable to those familiar with the facts of solar-terrestrial relationships—all the three great storms of the present cycle, those of September 18-19, 1941, March 20, 1940, and April 16, 1938, oc-



BRIGHT CHROMOSPHERE ERUPTIONS IN SUNSPOT GROUP
 PHOTOGRAPHED IN THE LIGHT OF LUMINOUS HYDROGEN VAPOR. *Left:* THE BRIGHT ERUPTION STARTING, TAKEN ON SEPTEMBER 17, 6:26 A.M., PACIFIC STANDARD TIME. *Right:* THE ERUPTION, GREATLY INCREASED IN BRIGHTNESS, TEN MINUTES LATER.

TABLE 1
GREAT MAGNETIC STORMS¹

Date	Ranges ²			Station	Remarks
	Declination	Horizontal intensity	Vertical intensity		
1859, Aug. 28-Sept. 7 1872, Feb. 4	140 ...	γ 700 (?) > 900	γ 400 (?) ...	Greenwich, England Bombay, India	Aurora seen at Bombay
1882, Nov. 17-21 . . .	115	> 1090	> 1000	Greenwich, England	Largest sunspot-group of that cycle on sun
1903, Oct. 31-Nov. 1. 1909, Sept. 25	186 210	> 950 > 1500	> 950 > 1100	Potsdam, Germany Potsdam, Germany	Lasted only about 10 hours
	68	800	235	San Juan, Puerto Rico	
1921, May 13-16 . . .	199 > 120	1000 > 800	1100 > 1000	Potsdam, Germany Cheltenham, Maryland	Aurora seen at Samoa
	96	> 1100	453	Watheroo, Western Australia	
1938, Apr. 16	320	1900	600	Potsdam, Germany	Lasted only about 10 hours
	25 291	1320 1120	118 1020	Huancayo, Peru Cheltenham, Maryland	
1940, Mar. 24-25 . . .	135 137	2300 850	900 1100	Potsdam, Germany Cheltenham, Maryland	Severe disturbance of power-circuits in North America
	21	1390	122	Huancayo, Peru	
1941, Sept. 18-19 . . .	264	2544	1390	Cheltenham, Maryland	Remarkable auroral display in eastern and mid-central parts of United States
	71	684	...	Watheroo, Western Australia	

¹ Expressed in minutes of arc for declination and in γ ($1\gamma = 0.00001$ gauss) for horizontal and vertical components.

² Table 1 is an extension of one appearing in "Geomagnetism" by S. Chapman and J. Bartels.

occurred after the sunspot-maximum. The great storm of May, 1921, occurred four years after the maximum in 1917 and the one of 1909 about three years after the maximum.

The accepted explanation of this apparent anomaly is that during the ascending part of the cycle the sunspots are in high heliographic latitudes from which radially directed streams of solar particles are less likely to reach the earth than they are if proceeding from lower heliographic latitudes where the sunspots are during the descending part of the cycle. Another fact—that more and greater storms occur around the equinoxes—finds a related explanation. Owing to the obliquity of the solar rotational axis with respect to the plane of the ecliptic, the earth is above different heliographic latitudes at different times

of the year. On September 7 and March 5 the earth attains its northernmost and southernmost heliographic positions and therefore is most nearly in a line with the center of the sun and the active zone on the sun's surface, so that radial streams of solar particles are most likely to encounter the earth at this time.

Thus when a sunspot-group crosses the solar meridian around the equinoxes during the descending part of the sunspot-cycle the earth is in the most favorable position to encounter a stream of solar particles. If that group is large and exhibits unusual activity at that critical time something is likely to happen. Happen it did in the present case and millions of Americans, even in the southern parts of the United States, witnessed one of the most magnificent auroral displays of recent times.

A. G. McNISH

THE WEATHER BUREAU—FIFTY YEARS OF PROGRESS

On June 30 of this year the Weather Bureau completed its 50th year as a civilian service. Its establishment in 1891 as a Bureau of the Department of Agriculture did not, however, represent its real beginning, as is shown in the following historical summary based on the Proceedings of the American Society of Civil Engineers for January, 1933.

Josiah Meigs, Commissioner of the United States General Land Office, established tri-daily observations at all Land Offices in 1817, this being the first attempt on the part of the Federal Government to make systematic observations on climatological phenomena. In the following year, the Surgeon-General of the Army issued an order requiring all surgeons in Army hospitals to keep observations on the weather. In 1825, the State of New York and, in 1837, the State of Pennsylvania, initiated statewide collection of weather data. In 1841, the United States Patent Office commenced the collection of such data upon a broader scope and, in 1847, the Smithsonian Institution inaugurated a system of organized observations. The first published

weather forecast based upon simultaneous telegraphic observations was inaugurated in 1849 by Professor Henry, of the Smithsonian Institution, and these forecasts were continued until 1861.

The plans for the present Weather Bureau were originated in part by Professor Abbe, director of the Mitchell Astronomical Observatory, at Cincinnati, during the period, 1868-70.

A bill based on these plans was passed by Congress in 1870 and provided:

for the taking of meteorological observations at military stations in the interior of the continent and at other points in states and territories of the United States, and for giving notice on the northern lakes and at the sea coast, by magnetic telegraph and marine signals, of the approach and force of storms.

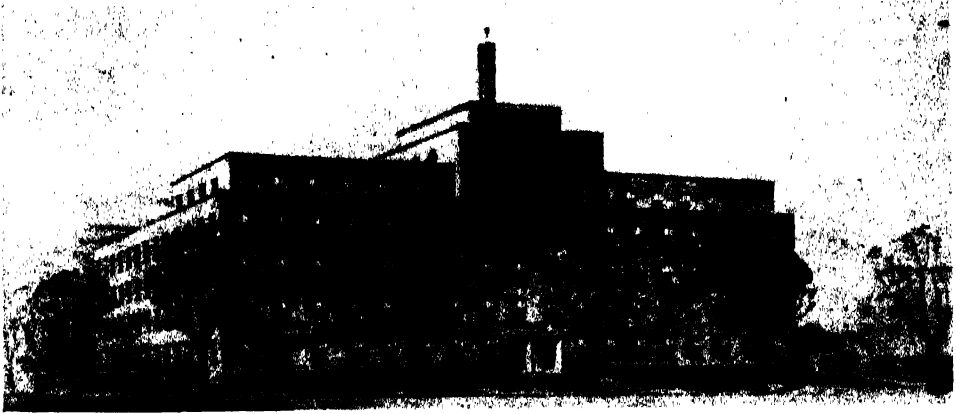
Under this act the service was begun as reported by the Chief Signal Officer in his Report to the Secretary of War for the fiscal year 1871:

On November 1, 1870, at 7:35 A.M., the first systematized synchronous meteoric reports ever



THE OLD WEATHER BUREAU BUILDING COMPLETED IN 1886

ITS INTERIOR DECORATIONS INDICATE THAT THE BUILDING MAY HAVE BEEN INTENDED FOR USE AS A CENTRAL AMERICAN EMBASSY. IT WAS ACQUIRED BY THE WAR DEPARTMENT IN 1888 AND FIRST OCCUPIED IN THE SAME YEAR BY THE METEOROLOGICAL SERVICE OF THE SIGNAL CORPS, THEN UNDER THE DIRECTION OF GENERAL A. W. GREELY.



ARCHITECT'S DRAWING OF THE PROPOSED ADMINISTRATION BUILDING OF THE U. S. WEATHER BUREAU. THE RIGHT-HAND THIRD OF THE BUILDING WAS COMPLETED AND OCCUPIED IN MAY OF THIS YEAR.

taken in the United States were read from the instruments by the observer-sergeant of the signal service at twenty-four stations, and placed upon the telegraphic wires for transmission.

With the delivery of these reports at Washington, and at the other cities and ports to which it has been arranged they should be sent, which delivery was made by 9 A.M., commenced the practical working of this division of the signal service in this country.

With this beginning, the national meteorological service continued to function as a unit of the Army Signal Corps until its transfer to the Department of Agriculture on July 1, 1891, where it remained for 49 years, lacking one day. By Presidential Reorganization Order No. IV, it was transferred to the Department of Commerce on June 30, 1940.

From the 24 stations mentioned in the Chief Signal Officer's report quoted above, the field network of observing and reporting stations under the Weather Bureau's supervision has grown to 800. Forecasting centers, beginning with the original one at Washington, now number fourteen, including those in Alaska, the Hawaiian Islands and Puerto Rico. Special demands, not fully satisfied by the general forecasts, have required the establishment of certain special services

—the Hurricane Warning service, the Aviation Weather service, the Fire-Weather service, the River and Flood service, the Fruit-frost service, the Winter Sports service—whose functions are implied by their service names. Forecasts, warnings and current information are conveyed to the public through the facilities of 600 radio stations, a mailing list of 25,000 daily maps and bulletins, automatic telephone announcements, storm warning displays, nation-wide teletype distribution and direct telephone and telegraphic report. The nation-wide observing organization includes upwards of 5,000 unpaid observers for the collection of climatological data in addition to a somewhat larger number for furnishing the specialized observations required in the special services mentioned above, and from ships at sea.

Besides the continuous round-the-clock operation of its various forecasting services and their innumerable applications to public life, the Climatological Service of the Weather Bureau has also an honorable though less generally conspicuous history. It is the business of this division to keep the weather records—to receive



FIRST UNIT OF THE NEW WEATHER BUREAU ADMINISTRATION BUILDING
ERECTED DURING 1940-41 ON THE GROUND DIRECTLY IN FRONT OF THE OLD BUILDING. BOTH BUILDINGS, THOUGH FULLY OCCUPIED, ARE STILL INSUFFICIENT TO HOUSE THE WASHINGTON STAFF. THE RADIOSONDE LABORATORY, THE INSTRUMENT AND PROCUREMENT SECTIONS, AND ONE RESEARCH UNIT OCCUPY RENTED SPACE IN OTHER OFFICE BUILDINGS NEARBY.

all observations after their immediate purpose has been served, to record systematically and to publish the measurements of temperature, rain, frosts, winds and other meteorological elements that make up one of the most complex national climates on earth. Although the value of these data will be obvious with respect to agriculture, manufacture, the public health, aviation and some other easily definable large-scale activities, their ultimate usefulness is literally beyond measure. In the 50 years of the Weather Bureau's civilian status the net work of climatological observing points has been increased from approximately 2,000 to over 5,000 stations and extended to Alaska, the Hawaiian Islands and the Caribbean; and no single unit of the Weather Bureau has contributed more significantly to the program of the national defense than has this one with its reliable long-term statistics upon the weather characteristics of the United States and its possessions.

Accompanying the growth and supporting the purpose of the direct services,

the theoretical researches of Weather Bureau meteorologists have contributed continuously to the knowledge and value of the science. The problem confronting the earlier investigators was essentially to discover from surface weather observations the complex secrets of an active atmosphere many miles in depth, in a state of ceaseless motion, and to a very large extent unsusceptible of direct observation. Even with this handicap, William Ferrel was able to produce his "Meteorological Researches" and other writings, and Humphreys his "Physics of the Air," to mention but two of the more notable examples. In addition to these, the *Bulletin of the Mount Weather Observatory* and the long series of the *Monthly Weather Review* are rich in contributions of lasting value to the science of meteorology.

From the modern scientific standpoint, developments in meteorology must be attributed in large part to the invention and refinement of methods for observing the conditions and actions of the upper levels of the atmosphere. Directions and

velocities of winds, systematically observed and plotted in the pilot balloon program begun in 1918, represent an important portion of this work; and more recently the development of the radiosonde has placed within reach invaluable data upon upper-level pressures, temperatures and humidities. The need and importance of this kind of information have of course always been apparent to meteorologists, and long before either airplane or radiosonde observations were possible, the Weather Bureau began gathering upper-air records by means of kites and occasional sounding balloon flights. These methods were displaced during the early 30's by airplane observations, made with instruments carried aloft at specified times and places. Although better than the earlier observations, these too were deficient, not only in number but also because flights frequently could not be risked during critical storm conditions. More recently, with its improvement as a meteorological measuring device, the radiosonde has displaced the airplane as a means for gathering upper air data. There are now in operation in the United States and possessions some 50 radiosonde stations taking observations twice a day.

The usefulness of these observations has already been clearly reflected in forecasts with more accurate timing and more complete description of weather behavior. In addition, the upper-air data have supplemented and clarified many of the working principles of the Air Mass and Frontal system of weather analysis and forecasting as it applies in the United States, and seem to offer good promise of a reliable extension of the time-period of forecasts. The fundamental ideas of the Air Mass method, known to meteorologists for well over a century, were first effectively developed and ap-

plied by J. Bjerknes, of the Norwegian Meteorological Service, during the first world war. That this system provides a far more systematic method for interpreting and predicting atmospheric actions than those previously used is in large part owing to the fact that it evaluates the significance not merely of surface observations but also of those taken throughout the vertical depth of the active atmosphere. There seems ample reason to believe that the use of this method, combined with continued analysis of the data upon which it primarily depends, will produce yet greater advances in the development of meteorology as a science and a practical contribution to the public good.

F. W. REICHELDERFER, *Chief*
U. S. WEATHER BUREAU



RELEASING A RADIOSONDE
DURING FLIGHT, WHICH USUALLY EXTENDS TO
HEIGHTS EXCEEDING TEN MILES, THE RADIOSONDE
TRANSMITS BY RADIO SIGNALS A CONTINUOUS
RECORD OF THE ATMOSPHERIC PRESSURE, TEM-
PERATURE AND HUMIDITY OF THE AIR THROUGH
WHICH IT ASCENDS.

CHARTER OF SCIENTIFIC FELLOWSHIP

At the conclusion of a meeting of the Division for the Social and International Relations of Science of the British Association for the Advancement of Science on September 27-29, its president, Sir Richard Gregory, announced a "Charter of Scientific Fellowship" which had been drawn up by a Committee of the Division and adopted by the council of the association.

For several years both the British Association and the American Association have been concerned with the interrelations of science and our social order. Every one has been aware of the profound effects of science upon social and political problems, as well as upon our ways of living. Many persons have advocated that scientists should more actively interest themselves in the consequences of their work. For the purpose of putting these ideas into effect, the British organized its new division in 1938, the American Association began to hold programs on Science and Society in 1937, the British and American Associations entered into cooperative arrangements in 1938, and the American Association appointed a special Committee on Science and Society in 1940.

What is a charter of scientific fellowship? Obviously it is a code for relationships among scientists. If science and scientists are as objective and impersonal as they are often said to be, such a code should set a new level for human relationships. It would be free from greed, unworthy ambition, intolerance and malevolence; it would exhibit the qualities of the Sermon on the Mount in the relations among scientific men.

Following a preamble of considerable length, the Charter of Scientific Principles adopted by the Council of the British Association is as follows:

1. Liberty to learn, opportunity to teach and power to understand are necessary for the "ex-

tension of knowledge, and we, as men of science, maintain that they can not be sacrificed without degradation to human life.

2. Communities depend for their existence, their survival and advancement, on knowledge of themselves and of the properties of things in the world around them.

3. All nations and all classes of society have contributed to the knowledge and utilization of natural resources, and to the understanding of the influence they exercise on human development.

4. The basic principles of science rely on independence combined with cooperation, and are influenced by the progressive needs of humanity.

5. Men of science are among the trustees of each generation's inheritance of natural knowledge. They are bound, therefore, to foster and increase that heritage by faithful guardianship and service to high ideals.

6. All groups of scientific workers are united in the Fellowship of the Commonwealth of Science, which has the world for its province and the discovery of truth as its highest aim.

7. The pursuit of scientific inquiry demands complete intellectual freedom and unrestricted international exchange of knowledge; and it can only flourish through the unfettered development of civilized life.

Six sessions were held at the meeting at which the British Association of Scientific Fellowship was announced. At the second of these sessions Mr. John G. Winant, Ambassador from the United States to Great Britain, served as chairman. The representatives of the American Association at the meeting were Dr. Lewis H. Weed, of Johns Hopkins University, and Dr. Edward Harvey Cushing, of Western Reserve University. The subjects for discussion at the six sessions of the meeting were: Science in Government, Science and Human Needs, Science and World Planning, Science and Technological Advance, Science and Post-War Relief and Science and the World Mind. The participants in the programs included such famous scientists as Professor A. V. Hill, member of Parliament and secretary of the Royal Society; Dr. P. W. Kuo, representative of the Chinese government in the fields of science and

education; Professor J. D. Bernal, Sir John Orr, Professor E. Volterra, Sir John Russell, Dr. Julian S. Huxley, Professor Max Born and Professor L. Hogben.

The degree to which science has increased human relationships was illustrated during the time of the meeting by a two-way radio discussion, arranged by the National Broadcasting Company, between British scientists assembled in London and scientists in America. Not only did the participants on the two sides of the Atlantic confer almost as though they were in the same room, but their words were broadcast throughout England and the United States. The participants in the discussions included Professor A. V. Hill, a Nobel Prize winner in physiology, Dr. Julian S. Huxley, Mme. Eve Curie, Professor Blackett and Mr. Ritchie, in London; and Ambassador Winant, Dr. Harold Urey, Nobel Prize

winner in chemistry, Dr. Franz Boas, and Waldemar Kaempffert, in New York.

The spirit of the London meeting and of the transatlantic discussion can not be illustrated better than by the closing words of Ambassador Winant:

We must recognize already that when we leave the battle fields of this war, we will move into a wounded world of immediate needs and crowded wants in which the healing hands of science and the constructive powers of mechanical arts are an essential part of any brave new world. In our great effort to reestablish political rights which is necessary if we are to have scientific progress and a free mind, we must keep constantly in mind the obligation of science to satisfy the primary needs of man, so that the essentials of life are recognized equally as a part of the rights of man. This is necessary if we are to have security. We must abolish both hunger and the sword as a means of forcing labor. In that way only can we satisfy human needs and give meaning to that equality which proclaimed for all men everywhere the right of life, liberty and the pursuit of happiness.

F. R. M.



AMERICAN PARTICIPANTS IN THE TWO-WAY RADIO DISCUSSION
AT THE TIME OF THE CONFERENCE ON "SCIENCE AND THE NEW WORLD ORDER." *Left: DR. HAROLD UREY AND WALDEMAR KAEMPFERT; right, front: DR. FRANZ BOAS.*

**THE PHILADELPHIA BIBLIOGRAPHICAL CENTER AND
UNION LIBRARY CATALOGUE**

In January, 1936, in Philadelphia's barn-like Commercial Museum, a force of 125 typists and 35 filers set to work. The typists sat beside microfilm reading machines transcribing on 3 × 5 library cards what they read on the illuminated images before them. The filers, after the cards had been checked for accuracy, arranged them alphabetically in trays.

These workers were men and women on the Philadelphia WPA rolls. Whether justly or not, WPA workers have been charged with raking leaves from one place to another and back again, with leaning on shovels and against themselves. But in this instance the usefulness of the project speaks for itself. After three years' work and the expen-

diture of nearly a quarter million man-hours and \$200,000, a union catalogue of 3,250,000 cards representing 5,000,000 books in nearly 150 libraries in and near Philadelphia had been completed.

Now known as the Philadelphia Bibliographical Center and Union Library Catalogue, it was the largest regional union catalogue in the country and second only in size to the union catalogue in the Library of Congress, which, founded in 1901, has 11,000,000 cards and is, of course, national in scope. This spring, with the addition of the 152d library in the Philadelphia area, the catalogue is now complete save for the addition of some 70,000 cards a year representing new accessions. Exclusive of



PREPARATION OF CARDS FROM MICROFILM READING-MACHINES
IN WHAT SEEMS A MAD-HOUSE, PERHAPS, TYPISTS ARE TRANSCRIBING THE LIBRARY CARDS OF THE PHILADELPHIA BIBLIOGRAPHICAL CENTER AND UNION LIBRARY CATALOGUE FROM MICROFILM READING-MACHINES. THE ACCURACY WAS EVEN HIGHER THAN IN TRANSCRIBING DIRECT FROM THE ORIGINAL CARDS BECAUSE OF THE LARGE SIZE OF THE IMAGE ON THE READING MACHINE.



MR. A. B. BERTHOLD, BIBLIOGRAPHER OF THE UNION LIBRARY CATALOGUE AIDS IN EDITING THE CARDS. IN THE MANY CASES OF DUPLICATION OF THE SAME BOOK IN MORE THAN ONE LIBRARY, ONLY THE TRANSCRIPT OF THE MOST COMPLETE ORIGINAL IS FILED.

\$45,000 for equipment and supervision, supplied principally by the Carnegie Corporation, it cost less than five cents to transcribe and file a card, a figure that has interested some librarians. The low cost was made possible by first photographing the original cards on microfilm (16mm), a method originated and first used in the Philadelphia Center.

For research workers in Philadelphia the usefulness of the new Bibliographical Center is obvious. Although inter-library loans can be obtained from virtually any important library in the United States through the national catalogue in Washington, the mails are slow, and the cost of postage and insurance from perhaps as far away as California mounts up. Why apply to Washington when a phone call to the Fine Arts Building of the University of Pennsylvania, where the center and catalogue are housed, may discover the book right at home and, if the borrower so desires, may even bring it to him by messenger?

But local investigators are not the only ones benefited. Thirty-six per cent. of

the items listed are not in the catalogue in Washington. Many of these relate to local history, but obviously, Philadelphia because of its early subscription libraries (such as the Library Company, founded by Franklin), its early prominence in medicine and law and as a center for Quakerism and the immigration of Germans, has rare and frequently unique holdings of Americana and even of English and other literatures and history.

Before the center was established, a prospective borrower might communicate separately with the University of Pennsylvania, which has especially rich collections in Medieval history, Elizabethan literature, the eighteenth century novel, Frankliniana, medicine, law, education, the history of chemistry, to name but a few; with the College of Physicians, said to have one of the finest medical libraries in the world; with the Library Company, which is rich in early American and European imprints; Haverford and Swarthmore Colleges, with their unrivalled collections on Quaker history;



THE FILING CASES OF THE BIBLIOGRAPHIC CENTER

ARE NOT NOTABLE FOR ELEGANCE. FOR ECONOMY THEY WERE CONSTRUCTED STURDILY BUT AS SIMPLY AS POSSIBLE. FOR THE MOST PART BOOKS ARE CATALOGUED BY AUTHOR'S NAME ONLY (WHEN ANONYMOUS BY TITLE). EDITIONS ARE CATALOGUED BY BOTH AUTHOR AND EDITOR.

etc.¹ But now inter-library loans can be made direct. That out-of-town workers are using the catalogue and the bibliographical service its staff supplies is revealed by the fact that they ask for an eighth of the more than 3,000 items now inquired for each month.

The purpose of the center is not primarily to provide a research worker with bibliographies, but rather to locate a book once the worker knows the name of

its author. It does, however, direct him to collections of bibliographical apparatus, as, for example, the unusually complete collection of the catalogues of English and other European libraries found in the Library of the University of Pennsylvania. It also provides a means of integrating and making more intelligent the current acquisitions of member libraries. Its fundamental purpose is to make the exceptional holdings of Philadelphia libraries better known by serving as a clearing-house on resources and services. It directs inquirers to the agencies from which they can get authoritative information. Librarians nowadays do not wish to keep their treasures from the eyes and hands of qualified users, and that to a large extent explains the generous cooperation given by member libraries.

¹ A full account of Philadelphia library resources is in "Philadelphia Libraries and Their Holdings," published this spring by the University of Pennsylvania Press (fifty cents). Perhaps for readers of THE SCIENTIFIC MONTHLY, special mention should be made of the libraries of the Academy of Natural Sciences and the Franklin Institute, which are superb in natural history and engineering respectively. The films used in making the union catalogue are available for inter-library loans. They provide a means of determining very rapidly the holdings of a particular library.

CORNELL M. DOWLIN

THE SCIENTIFIC MONTHLY

DECEMBER, 1941

DETERMINISM IN PRIMITIVE SOCIETY?

By Dr. JULIAN H. STEWARD

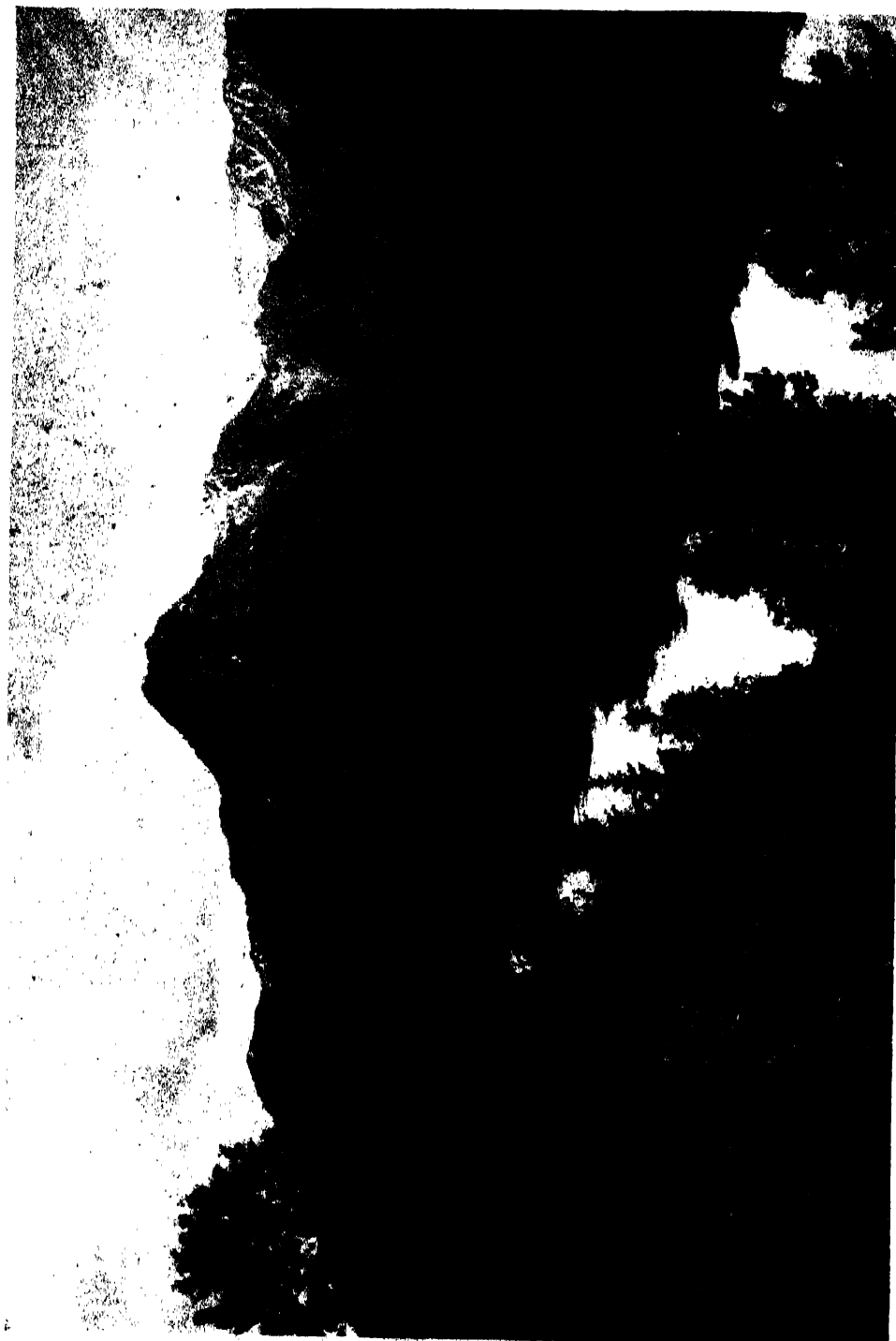
SENIOR ANTHROPOLOGIST, BUREAU OF AMERICAN ETHNOLOGY

THERE has recently been renewed interest in the general proposition, stated in many ways and with varying degrees of moderation, that technological and economic changes largely predetermine social and political trends. Politicians, business men and laymen argue the power of some form of "economic determinism" as against ideologies. What has anthropology, centering its attention largely on the simpler peoples of the world where it should be easier to isolate the causes of social change, to say of this proposition?

Anthropologists have long recognized that the spread of customs from one group of people to another—"diffusion" in anthropological terminology—accounts for at least nine tenths of the culture of any group. On its face, this would seem to assign any kind of economic determinism an insignificant role. An analysis of this problem, however, in the light of what is known of culture change among primitive peoples, both before and after they have experienced acculturation resulting from contact with European cultures, exposes its considerable complexity. Under certain conditions, subsistence patterns—that is, the activities concerned with acquiring food, clothing, shelter and other things indispensable to existence—have imposed very narrow limits on possible variation of social and economic organization.

Under other conditions, it is evident that considerable latitude is possible in the socio-economic structure. Before attempting any generalizations, therefore, anthropology is compelled to ascertain in specific circumstances the manner and extent to which subsistence patterns have affected the total culture.

Subsistence patterns have been extraordinarily potent in shaping the social organization of a number of primitive hunting and gathering peoples in different parts of the world. Among the Bushmen, African and Malaysian Negritos, Australians, Tasmanians, Fuegians, southern California Indians, and several others certain features of the relationship of man to his environment are very similar and have produced almost identical social patterns. All these peoples live in areas of slim food resources and low population density. To obtain adequate food, it is necessary that single families forage alone during most of the year. Larger population aggregates are possible only for brief periods of abundance when a few communal enterprises are carried on. Because hunting provides the most important food, it is customary for a man to remain in the territory in which he has been raised and has learned to know intimately. He hunts alone or with a few other men who do not venture beyond their territory and defend it from trespass by outsiders.



MOUNT ROCHER DÉBOULÉ FIRES ABOVE BULKLEY RIVER
WESTERNMOST HABITAT OF THE CARIBBE INDIANS. THE RIVER IS AN IMPORTANT SOURCE OF SALMON.

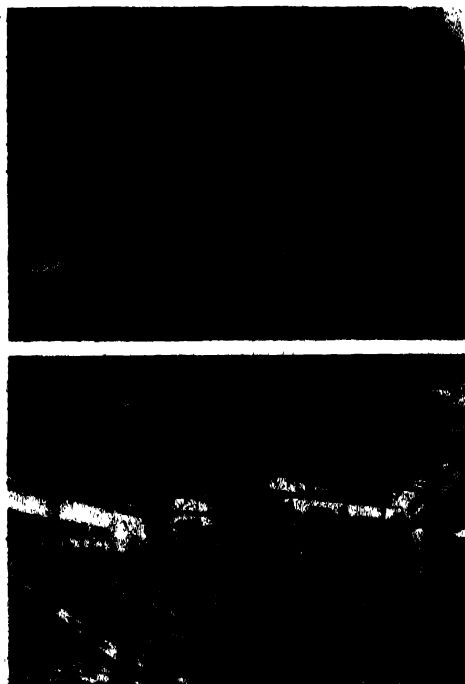
As the local group rarely numbers more than 50 people, its members are usually related so that it is necessary that a man take his wife from another group. Each group consequently consists of people related through the male line. It is a patrilineal, patrilocal, exogamous, land-owning band. This pattern is repeated so consistently under identical economic and environmental conditions that a cause-and-effect relationship between the latter and the former is unmistakable.¹

Although the essential social patterns of the tribes just mentioned developed directly from factors that are mainly economic, diffusion was also at work in some cases. In northern Australia, matrilineal moieties—dual divisions reckoning descent through the female line—had spread among many tribes and been superimposed on patrilineal bands to create a complicated system of marriage classes. In southern California patrilineal moieties had been adopted by several tribes with patrilineal bands. And among all these tribes, a number of minor details of society were clearly derived from neighboring areas.

Subsistence patterns imposed even narrower limits on the social structure of Shoshonean tribes in the Great Basin area of the western United States.² In aboriginal days, the Shoshoneans did little hunting, as game was too scarce. They relied predominantly on wild seeds that grow sparsely in the semi-deserts. Because these seeds occur somewhat erratically from year to year it was necessary that families, usually wandering alone in their food quest, gather seeds wherever they could be found. This brought overlapping subsistence areas and a complete lack of ownership of natural re-

sources. The lone family, therefore, was usually the maximum economic unit and, rarely enjoying the company of other families, it was the only stable social unit, being linked to other families only through loose kinship bonds.

But the entire socio-economic structure of certain Shoshoneans was altered by a single factor introduced by the White man. The horse was adopted at an early date by those groups occupying grass-



OLD TSIMSHIAN HOUSE
EXTERIOR AND INTERIOR. BUILT OF HAND HEWN
BOARDS TIED WITH WITHERS. IT WILL SOON BE A
SUBJECT FOR THE ARCHEOLOGIST.

lands. The transportation advantages of the horse not only enhanced the importance of hunting among those near bison country, but enabled considerable numbers of people to live together in permanent association. It was no longer necessary that families remain near their stored foods in various parts of the country; food could be transported to a central point. These Shoshoneans

¹ Julian H. Steward, "The Social and Economic Basis of Primitive Bands," In "Essays in Anthropology in Honor of Alfred L. Kroeber," Berkeley, California, 1936, pp. 331-350.

² SCIENTIFIC MONTHLY, 49: 524-537, December, 1939.



A FORT ST. JAMES CARRIER FAMILY AT LUNCH IN THE FRONT YARD

quickly developed bands of considerable size.

The question of what limitation subsistence patterns imposed on the social

structure of hunters and gatherers in a more fertile environment was investigated among the Carrier Indians of British Columbia. The Carrier Indians



CARRIER INDIANS AT FORT ST. JAMES, BRITISH COLUMBIA
MAKE MANY BIRCHBARK VESSELS FOR HOME USE AND FOR SALE

inhabit an area of comparatively abundant food resources. Like their Athapaskan-speaking relatives of the Mackenzie basin, they trapped fur-bearing animals and hunted large game characteristic of the north woods. But, like the tribes of the north Pacific coast, they also took considerable quantities of fish, especially salmon, from the headwaters of the Fraser and Skeena Rivers. Although less wealthy than the coast Indians, the Carrier found living not as precarious as among the tribes east of

during the summer and winter, respectively. In summer, people remained in permanent villages near their fisheries and caught great quantities of salmon. Communal enterprises, such as the construction of fish weirs, contributed to group solidarity. In late fall, when furs were prime, families, alone or in small groups, took to the streams and forests to trap beaver, muskrat, mink, fox and other fur-bearing animals and to hunt deer, bear and caribou. They remained, however, within easy distance of their



COWBOY JIG CONTEST AT THE ANNUAL STONEY CREEK CARRIER STAMPEDE
A GUITAR AND ACCORDION SUPPLY MUSIC.

the Continental Divide beyond the habitat of the salmon.

The history of the Carrier Indians is known in considerable detail during the century and a quarter that has elapsed since the first European visited them in 1805. Certain events during the prehistoric period can be inferred with reasonable certainty.

The Carrier subsistence pattern that was known at the beginning of the historic period probably extends back several centuries. It rested on a balance of complementary activities carried on

villages because hunger compelled them to return home from time to time to their stores of smoked salmon.

Carrier socio-economic organization must originally have been based on some kind of loose bands like those of the interior Athapaskans. If the Carrier were distinctive, it was probably because salmon gave them greater security and permitted permanent villages, whereas Athapaskans beyond the salmon habitat had to wander over their hunting lands throughout the year. There is no reason to believe that the Carrier had any kind

of private ownership of food resources. As among other Athapaskans, all members of the village or band probably had the right of using the group's fishing stations and hunting area.

In the course of time, however, the Carrier were exposed to influence from the Pacific coast, where the tribes had a strongly matrilineal society with an aristocracy based on wealth—a socio-economic organization unique among American Indians. The Northwest Coast tribes are organized in totemic moieties and

clans. A child belongs by birth to his mother's group. Each clan and moiety had certain hereditary titles of nobility which were held by individual men and passed on to their sisters' sons, thus remaining in the clan and family. With these titles went rights to the produce of certain fisheries and other natural resources and the privilege of requiring one's clansmen of the common class to help amass goods for great feasts at which presents were distributed to rival chiefs or nobles. These feasts, called potlatches, were essential to establish a title and the wealth it represented, for the Northwest Coast point of view held that proof of wealth lay in distributing rather than hoarding goods.

Completely foreign to Athapaskan society as this Northwest Coast pattern would seem, it spread up the Skeena River from the Tsimshian Indians to the Carrier of Babine Lake and finally to those of Stuart Lake. Its appearance among the Carrier, however, was in comparatively late prehistoric times, for it was still spreading when the White man arrived. Some Carrier adopted it only within the past hundred years. The Stuart Lake people, however, had the whole system when the Europeans first arrived as several facts show. The succession of matrilineally inherited land and titles can be traced back to this time. Moreover, several historic incidents demonstrate the importance of wealth to the early Carrier. It is related that in 1823 James Douglas, who was in charge of Fort St. James, had two Indians put to death for the murder of two soldiers. The great chief Kwah entered the fort to avenge the matter. He objected not to the death sentence imposed on the Indians but to their bodies having been thrown to dogs. As Kwah threatened to kill Douglas, a quick-thinking woman began to potlatch him with tobacco, blankets and other goods thrown from the loft. No Carrier nobleman could



COMPLICATED DEADFALL TRAPS
FORMERLY USED BY THE CARRIER INDIAN FOR
CATCHING FUR-BEARING ANIMALS.

commit murder in the face of such gifts and Douglas's life was spared.

So far as can be ascertained, the transition from a simple band system to the Northwest Coast type of society occurred without a single important change in the methods of producing wealth. Hunting, fishing and fur-trapping were still carried on with devices that are widespread and clearly old in the north—bows and arrows, traps, nets and snares. Innovations were not in methods of production but in ownership and distribution. Land that previously had belonged to the whole group was now divided among men holding potlatch titles. Other people continued to live on the produce of this land but might be obliged to supply the needs of their potlatching nobleman, who might also be a kinsman and a source of some pride to them. In short, wealth was now owned and much of it consumed by a hereditary aristocracy.

The only economic factor that must be considered in this new Carrier social order was salmon fishing. The wealth that salmon made possible was insufficient to create a new system, but without it the system could not have been introduced. This is shown by the distribution of clans and potlatching. Whereas they were finally adopted by practically all the tribes on the salmon streams west of the Continental Divide in northern British Columbia, they did not and almost certainly could not have spread to the poorer Athapaskans of the Mackenzie basin beyond the habitat of the salmon.

The first effect of contact with the White man was to intensify rather than alter the motivations and structure of Carrier society. Steel traps made it possible to take more furs, guns to shoot more game and steel tools to construct weirs that would catch more salmon. The fur-trade introduced a wealth of European goods. Potlatch guests enjoyed presents in greater variety and quantity than ever. But at best, Carrier



CARRIER NONAGENARIAN
AT FORT ST. JAMES AGES ARE KNOWN THROUGH
CHURCH RECORDS.

potlatches were sorry affairs compared with those held by Indians on the coast, where natural resources are far greater. A wealthy coast noble might not only distribute quantities of food, hundreds of Hudson's Bay blankets, and other presents, but, to prove that his wealth was unlimited, kill a slave or burn a canoe in sheer bravado. A potlatching Carrier gave each guest a bit of food, perhaps a pair of moccasins or leggings, and a quarter or a sixth of a Hudson's Bay blanket. It was said that a man who had been potlatched often might receive enough pieces of blanket to sew them together into a whole blanket!

In the course of time, other influences emanating from the White man began to undermine the native Carrier system. But the transition to a new kind of society was effected gradually, through a series of cultural reintegrations. The Carrier experienced a minimum of the shock that has demoralized so many



THE BULKLEY AND BABINE RIVERS, FLOWING OUT OF CARRIER TERRITORY
JOIN AT HAZLETON TO FORM THE SKEENA RIVER IN TSIMSHIAN COUNTRY.



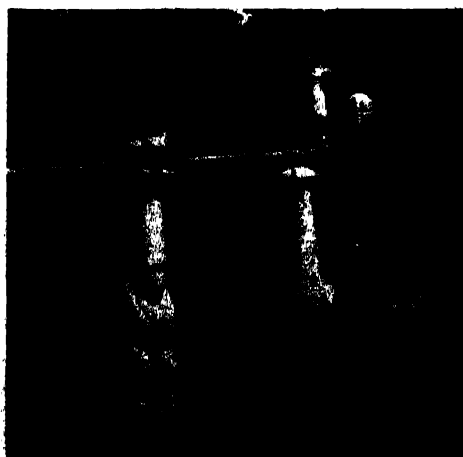
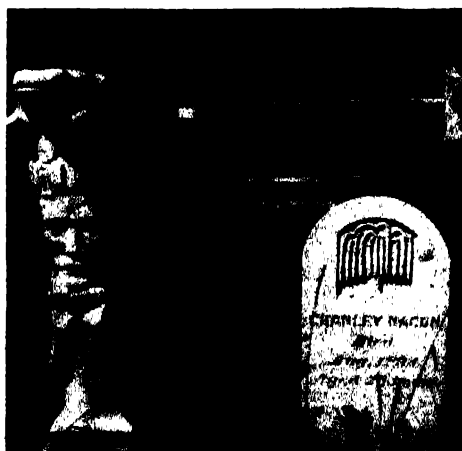
THE LOWER SKEENA RIVER, ONE OF THE MAIN SALMON STREAMS
IN BRITISH COLUMBIA. IT FLOWS THROUGH MOUNTAIN RANGES SCULPTURED BY HUGE GLACIERS THAT
DESCEND NEARLY TO THE SEA LEVEL.

Indian tribes after the impact of European culture on their own. Some of the ease with which change was accomplished may be attributed to the powerful personality of Father Morice, a Catholic missionary among them during the crucial years of their transformation. An historian and ethnographer, Father Morice studied the native Carrier culture and succeeded not only in stamping out many features disapproved by the Church but in developing the Carrier along new lines.

One of the first blows at the native system was to disrupt the mechanism for inheriting wealth and titles by banning cross-cousin marriage. It had been the custom that a man marry his mother's brother's daughter, live for some years in his uncle's household, and finally inherit his uncle's land and title. With a prohibition on cousin marriage, this inheritance machinery was thrown out of gear. It was still possible, of course, for a man to give his wealth and titles to his sister's son but, without cross-cousin marriage, his own daughter received nothing, so that these were alienated from his immediate family. Moreover, the Carrier were continually exposed to the White man's system of patrilineal ownership and inheritance. In the course of time, therefore, certain men came to consider it better to divide their estates among their own sons and repudiate the ancient obligation to give them to their nephews. One of the first to follow this independent course was Chief Kwah, owner of the highest titles and largest territory at Fort St. James. He divided his land equally among all his sons. An increasing number of men followed Kwah's example so that to-day very few Carrier families lack trapping grounds. Descent from father to son is the rule.

The new system of land tenure and inheritance in turn destroyed the basis of the old titles and potlatching. For a few years, men continued to pass their

titles to their nephews even while giving their land to their own sons. But a title is worthless unless a potlatch feast can be held to establish it, and a potlatch can not be given without ample resources. Potlatching therefore was doomed and titles were empty. One of



TSMISHIAN GRAVE STONES
IN THE HAZLETON CEMETERY SHOW A MIXTURE OF
CHRISTIANITY AND TOTEMISM. FROM WOODEN
MODELS CARVED BY INDIANS, PROFESSIONAL STONE
CUTTERS REPRODUCE THESE IN MARBLE.

Kwah's sons attempted to usurp Kwah's title which, by the former rule, should have gone to the nephew. This not only violated native usage but, having little wealth, Kwah's son was unable to pot-

latch for his title. He was refused recognition. To-day most Stuart Lake Carrier not only do not know who would be eligible for titles but have forgotten what most of the titles were.

Potlatching was also undermined when the Indians began to learn that it is better to husband goods than to give them away. The importance of this became very clear after the fur take had begun seriously to decline as a result of immoderate trapping with steel traps and after the salmon catch had all but vanished when the government prohibited the use of weirs and when the down-stream canneries cut heavily into each salmon run. Under aboriginal conditions, depleted fortunes could have been restored in time with hard work. Now, with reduced resources, potlatching ate into capital that would take many years to replenish and tended to pauperize the common people who had to supply potlatch goods. In a few parts of British Columbia where secret potlatches are occasionally held

to-day in defiance of Provincial law, public officials are no little annoyed that commoners who have impoverished themselves for potlatches should clamor for government relief!

Among the last features of the old Carrier social system to fade were the matrilineal, exogamous clans. These could, of course, have persisted after potlatching was abandoned. But they were weakened when the Indians accepted Catholicism. The clans had consisted of people who felt themselves related to one another because they had the common bond of an animal totem as well as economic functions. When the Catholic Church destroyed the system of myths and beliefs that had sanctioned the supernatural nature of these totems, the bond between clansmen was greatly weakened. The sense of kinship began to fade and marriages between clan members became more frequent.

Present-day Carrier society at Stuart Lake consists of individual families that



CARRIER WOMAN AND DAUGHTER-IN-LAW



SMOKE HOUSE FOR DRIED FISH AND MEAT WITH NATIVE TYPE BARK ROOF

have exclusive rights to certain trap-lines that are registered with and protected by the Provincial Government. The family is the kinship and economic unit. Potlatching, status based on wealth and exogamous clans have disappeared. The transition to the new socio-economic system was caused mainly by non-economic factors—absorption of the White man's ideology, especially Catholicism. Depletion of native resources was only an incidental, contributing factor. Its effect will probably be consummated in the future, when the native economy gradually gives place to a system of jobs and wages and the Carrier are absorbed in the broader economy of the White man.

From this review, it is evident that

the influence of subsistence patterns on the general form of socio-economic organization is great among the hunting and gathering peoples in areas of low productivity. Among the Carrier, at least, the framework of a given economy permitted several very unlike kinds of society, the choice between them depending on the influence of ideas from other peoples rather than upon economic necessity. Anthropology will not, however, be in a position to formulate any important generalizations about determinism in social change until this problem has been analyzed in many societies of different kinds. Each analysis must clarify the complex interaction of economic technology, environment, socio-economic organization and diffusion of ideas.



RUGGED SOUTHERN ALPS. FOX GLACIER, SOUTH ISLAND
IN SCENIC BEAUTY AS WELL AS STRUCTURE THESE ALPS RESEMBLE THE ALPS OF SWITZERLAND.
ACTIVE GLACIERS DESCEND THE MOUNTAIN VALLEYS ALMOST TO SEA LEVEL.

SOME PROBLEMS IN NEW ZEALAND'S POLITICAL GEOGRAPHY

By Dr. ADELBERT K. BOTTS

ASSOCIATE PROFESSOR OF GEOGRAPHY, NEW JERSEY STATE TEACHERS COLLEGE AT TRENTON

The stronger the vicinal location, the more dependent is the people upon the neighboring states, but the more potent the influence which it can, under certain circumstances, exert upon them. . . . The stronger the natural location, on the other hand, the more independent is the people and the more strongly marked is the national character.

—*Scmple.*

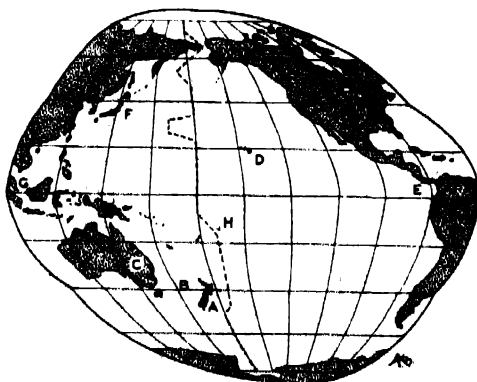
STRONG natural location dominates the political life of New Zealand. Thousands of miles of water isolate her from the centers of world activity, and twelve hundred miles of water form an effective barrier between her and her nearest continental neighbor, Australia. Independence characterizes the political and social life but not the economic activities of the smallest dominion.

It is common for New Zealanders to consider their independence practically as complete as that of the United States. It is, so far as their political activity and social and governmental matters are concerned. On the other hand, strong sentimental ties and economic dependence upon Great Britain contrast sharply with, and in many respects counteract the natural tendencies toward, independence.

To outside observers living among the New Zealanders for several months before the present conflict in Europe broke it was readily evident that New Zealand was eminently loyal to Britain. There were signs on every hand that as soon as England moved toward war the small dominion would be closely in her wake. In fact, one could not help feeling that on frequent occasions, the "colonials" were distinctly impatient with the toler-

ance shown toward the dictators by officials "at home."

By October, 1940, New Zealanders were deeply involved. Besides building a large home reserve, sending many men to the Near East, providing huge quantities of butter, wool and cheese for the mother country, these people further expressed their loyalty by enacting a new and drastic loan law and excess profits tax. By its enactment 15,000 individuals and 3,000 corporations will pay the government £8,000,000 (\$25,920,000.00) as a war loan without interest for three years.

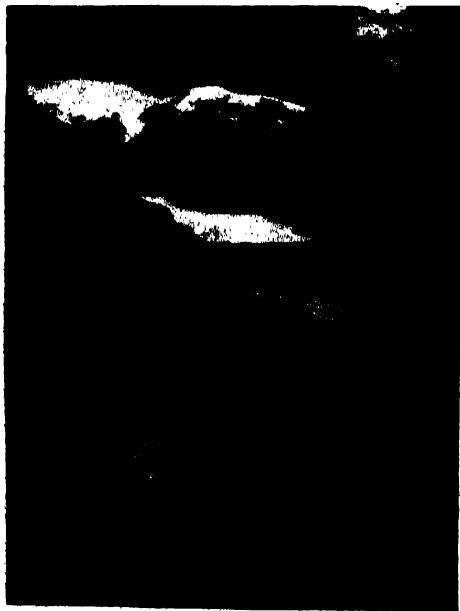


NATURAL LOCATION OF NEW ZEALAND
NEW ZEALAND (A), ONE THOUSAND MILES FROM NORTH TO SOUTH, IS SEPARATED FROM ITS NEAREST GREAT NEIGHBOR, AUSTRALIA (C), BY THE TASMAN SEA (B), 1,200 MILES WIDE. THE HAWAIIAN ISLANDS (D), WHERE MUCH OF OUR PACIFIC FLEET IS STATIONED, LIES 3,800 MILES NORTHEAST OF AUCKLAND. A SECONDARY AMERICAN SEA BASE IS LOCATED AT PAGO PAGO IN THE SAMOAN ISLANDS (H). THESE TWO POINTS TOGETHER WITH SINGAPORE (G) FORM THE STRATEGIC DEFENSE "LINE" BETWEEN THE TWO SOUTH PACIFIC DOMINIONS AND JAPAN (F). PANAMA CANAL (E) IS IMPORTANT AS AN ALTERNATIVE GATEWAY FROM THE SOUTH PACIFIC TO ENGLAND.

The new tax rate will be 60 per cent. of profits remaining after deduction of the existing income, social security and national security taxes.

The problems of participation in the present world struggle in Europe do not completely obscure the concern of these people for the international problems of the Pacific area. New Zealand fears Japan—not with a tangible fear but with a subconscious realization of her own weakness and of the prizes she might possess for a conquering Japan.

During a brief visit in Dunedin in May, 1939, the writer spent an evening with an educator of that community. Early in the evening the host had to leave to attend a meeting of school officials. Their task that evening was to work out details for the evacuation of Dunedin's school children in case of an air raid. To an American the idea seemed fantastic.



FRANZ JOSEF GLACIER

AS IT IS SEEN FROM OUTLOOK POINT. THE MOUNTAINOUS AND FIORDED SOUTHWEST COASTAL REGION IS PRACTICALLY UNINHABITED, BUT PEOPLE TRAVEL THOUSANDS OF MILES JUST TO EXPERIENCE THE GRANDEUR OF ITS SCENIC BEAUTY.

Dunedin is at the southern end of one of the most isolated countries in the world, but is taking serious steps to prevent an air raid disaster. And she is not alone in her anxiety. Each of the other New Zealand cities is taking similar precautions.

There are several good reasons for their concern. Japan is not so far from New Zealand as most of us assume, especially when we think in terms of island stepping stones. For almost half a century Japan has been expanding farther and farther south. Where she has been unable to conquer territory, as in Formosa and China, she has used more subtle means, some of them peaceful. After the last war she received mandates over the former German island groups, Mariana, Caroline and Marshall, territorial island bases in the west central Pacific. For years the Japanese have been moving into the Philippines. Although the Japanese are not numerically dominant, their attitudes and organization make them a group to be reckoned with. New Zealand looks upon the Philippine situation as a possible threat to herself if the present plans for Philippine independence materialize. With realism characteristic of their European associates the New Zealanders expect Japan to move into the Philippines when the Americans move out. Nothing is much more potent as a cause for jitters than the realization that Japan is moving closer and closer to New Zealand.

Observing a world map, we are likely to assume that New Zealand has little to offer Japan as an object of conquest. Certainly her bulk does not impress one who has a continental viewpoint. But Japan's viewpoint is not continental. She is an island country herself and can appreciate the resources and advantages of New Zealand.

The latter is about two thirds as large as Japan, but much richer in agricultural resources. The amount of cultiv-

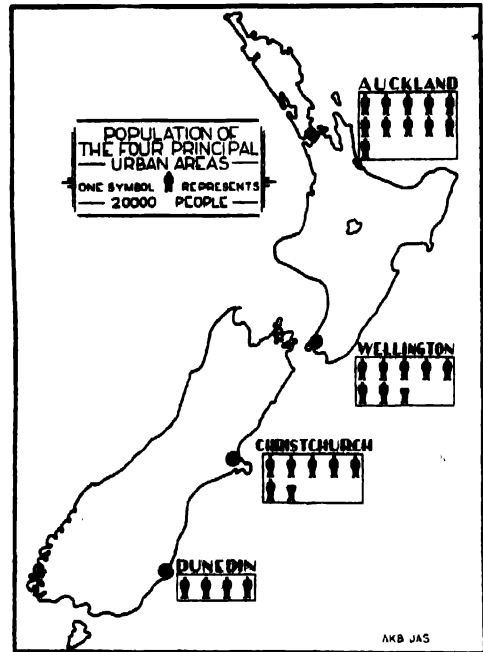
able land in New Zealand is greater than that in Japan. Japan with about twenty-two thousand square miles of cultivable land supports almost seventy million human beings. New Zealand, on the other hand, with nearly twenty-nine thousand square miles of cultivable land supports only one and one-half million inhabitants. Underpopulation in New Zealand is almost as serious a problem as is overpopulation in Japan.

New Zealand lies between thirty degrees and forty-eight degrees south latitude. Japan lies between thirty degrees and forty-five degrees north latitude. Climatically they are similar, although Japan experiences greater temperature extremes because it lies in the immediate lee of a tremendous continent, while New Zealand is separated from its nearest continental neighbor by the broad Tasman Sea.

From the point of view of political geography, New Zealand is not an easy land to defend. The sparse population is scattered over the coastal lowland throughout the entire thousand miles of north and south extent with major concentrations at four widely separated points.

The largest urban area, Auckland and its suburban communities, with about one seventh of the total population of New Zealand, occupies a narrow isthmus in the northern part of the North Island. The island there is less than six miles wide. On the east it faces the Pacific and on the west, the Tasman Sea. It may be approached from either side; but only the eastern side can accommodate oceanic traffic. The task of providing defense for that crowded isthmus is a major military problem.

About four hundred miles south of Auckland, at the southern end of the North Island is the capital, Wellington, a city of 125,000. It has somewhat better natural protection than Auckland, but is vulnerable because of the concentration of its industrial developments.



POPULATION DISTRIBUTION

THE FOUR PRINCIPAL URBAN AREAS OF NEW ZEALAND ARE ALL COASTAL COMMUNITIES AND CONTAIN 580,000 PEOPLE, APPROXIMATELY ONE THIRD OF THE TOTAL DOMINION POPULATION. THE PROGRESSIVE DECREASE IN SIZE FROM NORTH TO SOUTH REFLECTS LARGELY THE INFLUENCE OF ACCESSIBILITY TO WORLD TRADE ROUTES.

The South Island has two important population concentrations also, one at Christchurch and the other at Dunedin. In addition, there are smaller concentrations forming an intermittent line of population on all the coasts except on the southwest part of the South Island. In no case are there significant population concentrations at any points more than twenty-five or thirty miles from the sea.

With such a long thin line of population the cost of adequate defense against aggressive attack is prohibitive to a population of one and one-half million. That is not to imply that New Zealand is not spending for its own defense. She is, and highly too. But the task is a huge one.

Doubtless real aggressive warfare in that part of the Pacific would do much



AIR PHOTOGRAPH OF AUCKLAND HARBORS

AUCKLAND OCCUPIES A NARROW ISTHMUS BETWEEN THE TASMAN SEA AND THE PACIFIC OCEAN. ONLY THE WAITEMATA HARBOR ON THE PACIFIC SIDE IS OF ANY VALUE FOR OCEAN SHIPPING. THE ENTRANCE TO MANUKAU HARBOR IS TOO SHALLOW FOR SAFE USE.

to unite the two dominions of Australia and New Zealand into a much closer union than either is willing to advocate at the present time. Also both countries are likely to favor closer ties with the United States. Favorable trade concessions with the United States are quite likely if the South Pacific countries can be made to feel that we are sincerely interested in their security. The recent appointment of our first minister to Australia seems to indicate the truth of that assumption. It is much better for those countries to sacrifice some of the independence nature has given them in order to secure the protection of a country of their choice than it is to lay themselves open to the conquest of uncongenial "foreigners."

Dependence on the strong arm of Britain was not a matter of blind faith. New Zealand and Australia got much consolation out of the base at Singapore

and they gladly gave aid to the mother country in exchange for the help they hoped to receive from "Home" if the occasion arose.

Thoughtful New Zealanders recognize the principal flaw in that arrangement. It is evident that if England weakens, or if Pacific troubles intensify while the home land is busily engaged in Europe, the help they have bargained for can not be delivered. The only solace in that case is the United States.

It is remarkable the amount of satisfaction New Zealanders get out of our Pacific Fleet. They look upon it—if not as their first line of defense—certainly as a major bulwark against Japanese aggression upon English-speaking lands of the Pacific. All through New Zealand and among all classes of people one hears most positive evidence of such an attitude. They apparently have absolute confidence that the United States would

not stand idly by and let them be gobbled up by any Eastern Power. At least that was their belief before September, 1939.

The problem of the density of New Zealand's population (about 16 per square mile) is fully as important as its problem of population distribution. A million and a half people occupying a land which could support ten million in comfort is a serious geographic and political matter. Protecting the space against the designs of "people without room" assumes considerable proportions. There is constantly the feeling that, if the owners do not use the country more economically from an international point of view, some one else will. Population increase becomes, at least academically, a popular and much discussed topic. Obviously, the intelligent thing is for New Zealand to increase her population and use her space adequately. The only difficulty is that she can not do it. There

are several reasons why New Zealand can not readily relieve the dangers of under-population.

The two most popular formulas for improving the situations are: first, increasing the relative birth rate, and, second, immigration. Observed fact tells us that the first can be no solution in this case. In spite of a governmental campaign to increase the birth rate, statistics for 1936 and for 1937 indicate that the net reproductive rate is not sufficient to maintain the population at its present figure. The birth rate is rising slightly but not sufficiently to encourage any one to believe that New Zealand can ever achieve optimum population density through her own reproduction.

Our own country achieved its present density (41 per square mile) mostly by means of immigration. It is a thoroughly effective way to populate a country but carries with it a number of



AUCKLAND'S MAIN BUSINESS DISTRICT ON WAITEMATA HARBOR
THE LOWER LEFT FOREGROUND SHOWS TWO OF THE PRINCIPAL OVER-SEAS DOCKS; THE LOWER RIGHT FOREGROUND SHOWS THE FERRY DOCKS. AT THE CENTER OF THE PICTURE IS QUEEN STREET, THE COMMERCIAL CENTER OF THE CITY.



Courtesy Dorothy Ames

MOUNT EGMONT, AN EXTINCT VOLCANO IN PRODUCTIVE DAIRY REGIONS

ALMOST ALL THE LOWLAND AREA IS DEVOTED TO GRASSLAND AGRICULTURE. TARANAKI REGION, IN WHICH THIS MOUNTAIN IS LOCATED, LIES ON THE HUMID SOUTHWEST CORNER OF THE NORTH ISLAND. BOTH WINTERS AND SUMMERS ARE EXCEEDINGLY MILD.

handicaps. We have practically discontinued the process and so has New Zealand, and for approximately the same reasons. In the present social order it is quite impossible for nationals to meet the economic competition of the immigrant and at the same time maintain the standard of living to which they have become accustomed—or to which they hope to become accustomed. Socialized legislation is a definite deterrent to immigration.

Usually, in the middle latitudes, those people with meager economic and social resources or opportunities migrate most readily and in greatest numbers. They bring to the new country only their skill and man power. In a new and undeveloped country that is sufficient. But New Zealand is no longer a new and undeveloped country. She has reached a high stage in her present type of economic and social organization. She maintains a high standard of living and will not permit any class to be oppressed. But she wants to retain the benefits of that organization for those who have worked to achieve it. Immigrants simply do not fit into the scheme of things unless they have sufficient wealth to maintain a standard of living equal to that of the average New Zealand working man. The chances are, if a migrant has that much wealth in his home land he will be quite happy to stay there and enjoy it.

There are very few opportunities in New Zealand for specialists or for people with highly developed skills. Such people are social and economic luxuries beyond the financial reach of a country with limited population and modest means. The fact prevents specialists from other countries from moving to New Zealand. Much worse, it costs New Zealand the loss by emigration of many of her most promising sons. It has long been a cause for annoyance among New

Zealanders that her Rhodes Scholars and other highly trained young men have chosen the United Kingdom rather than their home land as a permanent residence after their period of training is past. Great Britain shows great eagerness in acquiring intelligent young scholars from the dominion. New Zealand appreciates the tribute, but considers it small compensation for her loss.

There are certainly many oppressed people who would welcome a chance to try their luck in a land of opportunity. Why should not an underpopulated land such as New Zealand allow them to take that chance? There are three reasons: In the first place, many of these people without opportunities at home belong to races quite different from the race of the governing people in the new country. No country now is willing to assume the difficulties of a racial minority group if that can be avoided.

Against immigrants of the same race or even of the same original nationality there are the other two objections:

The most effective way for immigrants to establish themselves is to sell their labor or the products of their labor at a lower price than others will accept. While they do that they must live on a low standard. In order to meet the competition, established labor must cut wages and lower standards. That obviously is not a likely course for New Zealand's labor union controlled government to foster.

The only other way in which the country can be made attractive to immigrants is to subsidize the immigrant sufficiently so that he can maintain an acceptable standard of living for the country and, at the same time, compete with established labor on its own level. To carry this out on any large scale would increase materially the tax burden with which the country is already oppressed. Regardless of values it is not a likely solu-

tion to the problem. Under any circumstances the benefits would be too distant and the expense too immediate for any transitory political organization to face even if it were inclined to attempt the task.

Several years ago an attempt at the application of a scheme of the last mentioned type was attempted. A system of assisted immigration was put into effect but has practically ceased to operate. The general scheme of governmental assistance to immigrants is based on nomination by a person already dwelling in New Zealand, who undertakes to find employment for his nominee. He must guarantee that his nominee will reside at least five years in New Zealand. Since 1925 not more than seven thousand immigrants have been assisted in that manner and during the years 1933-37 inclusive the greatest number assisted in any one year was eleven.

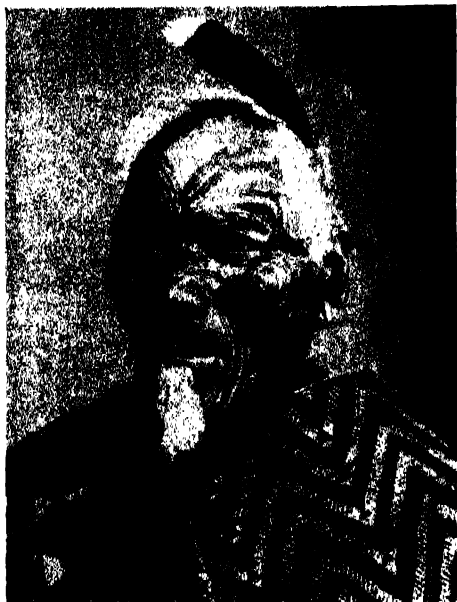
Homogeneity is characteristic of the

present population of New Zealand. Approximately 95 per cent. of the total population is of British descent. Slight provincial differences have resulted from the dissimilar geographic environments of the widely separated larger communities. But common descent with its many traditions, a strong central government and common economic and international problems bind the parts closely together. The only significant minority population group is the Maori native. Even they are so much involved in the general New Zealand culture and are gaining so much from their contacts with the British that it is certainly incorrect to think of the Maoris as constituting a minority problem in the sense that those words imply to-day.

New Zealanders are generally proud of their treatment of the Maori. During the hundred years of close contact, in exchange for the land which he formerly owned, the British have transformed the



POI DANCERS IN ROTORUA DRESSED IN NATIVE COSTUME
ON CEREMONIAL OCCASIONS AND FOR THE BENEFIT OF TOURISTS, THE MAORIS STILL DRESS THIS WAY AND DANCE THEIR NATIVE DANCER. AT OTHER TIMES THEY LIVE VERY NORMAL LIVES AS ORDINARY PARTICIPATING CITIZENS OF THE DOMINION.



MAHI POKI

MAHI POKI WAS ONE OF THE CHIEFS WHO EXPERIENCED THE FIRST IMPACT OF EUROPEAN CIVILIZATION UPON THE POLYNESIAN STONE AGE CIVILIZATION OF HIS ANCESTORS. HE AND HIS COLLEAGUES FOUGHT FOR THE PRESERVATION OF THE GOOD LIFE AS THEY HAD KNOWN IT BEFORE THE OUTSIDE WORLD THRUST ITSELF UPON THEM.

Maoris from exceedingly war-like, stone age cannibals into peaceful, industrious citizens. It is generally agreed that the Maori fared better at the hands of the New Zealander than the Indian did at the hands of the American. It is also evident that the Maori enjoys much greater economic and social equality with his pakeha (European) neighbors than is the case with our American Negro.

However, it is not quite fair to attribute this better treatment to a higher sense of social justice on the part of the British. Such is hardly the case, and many New Zealanders recognize the fact. The Maori has never been an economic threat to the Europeans. His numbers, about 5 per cent. of the total population, are not great enough to cause any serious economic conflicts. The Maori repro-



MATTIU TE HAU

THE MAORI OF THE PRESENT DAY HAS ADOPTED MANY CUSTOMS OF EUROPEAN CIVILIZATION, BUT THEIR LOVE FOR THEIR NATIVE LAND IS JUST AS STRONG AS THAT OF THEIR ANCESTORS. IN BOTH WORLD WARS MANY MAORI LADS HAVE MARCHED SHOULDER TO SHOULDER WITH THEIR "PAKEHA" BROTHERS IN DEFENSE OF CIVILIZATION.

ductive rate is higher than that of the British New Zealanders; but in an underpopulated country that is not likely to cause any difficulties for many years, if ever.

Credit must certainly be given to both these ethnic groups for the admirable way in which they have taken advantage of their opportunities to live together peaceably and fairly. There is surprisingly little race prejudice. Intermarriage is not uncommon and carries with it, none of the social ostracism usual in our country. In proportion to the size of the group the natives and mixed population have produced their full share of New Zealand's notables. Among them are Sir Aparana Ngata, a member of parliament, at one time a member of the Cabinet, and reputedly the greatest liv-

ing orator in the country; "Princess" Te Puia, a Jane Addams to the Waikato Maoris; Dr. Peter Buck, the director of Bishop Museum in Honolulu and a leading anthropologist on the staff at Yale University; and Dr. L. H. Potaka, member of Byrd's second Antarctic Expedition. A social order which permits and encourages the development of such talent is indeed commendable. The Maoris have so far adopted the European culture of their British neighbors that they think about world affairs in a characteristically European manner. In the last war the Maoris carried their full share of the burden. In the present conflict they are again joining the military forces for the protection of their common country. Plans are now under way for the formation of an all-Maori battalion of the men now enrolled and those who are ready to enlist.

Economically, New Zealand is far from achieving the independence Simple ascribes to isolated countries. Her resources are principally agricultural. She possesses sufficient good quality coal for her own needs but is practically devoid of economically valuable iron, the other basis of modern industrial development. No petroleum deposits of significance have been discovered; but her water power resources are abundant and well developed. Forests were once plentiful and still are in many localities. Some reforestation has been accomplished but not in sufficient amounts to compensate for the ruthless deforestation practices of the last half century.

Some degree of self-sufficiency in manufacturing is maintained by virtue of an exorbitant import tariff. Persons engaged in manufacturing industries constitute approximately 6 per cent. of the



ARAPUNI POWER STATION ON THE WAIKATO RIVER

NEW ZEALAND HAS AN ABUNDANCE OF POWER FOR HER INDUSTRIES FROM COAL AND WATER. HERE THE WAIKATO RIVER WAS DIVERTED FROM ITS FORMER COURSE BY VOLCANIC ACTIVITY. THE POWER FROM THIS STATION CONTRIBUTES LARGELY TO THE NEEDS OF ONE OF THE MAJOR DAIRY REGIONS OF THE NORTH ISLAND. IN NEW ZEALAND THE USE OF ELECTRICITY IS ALMOST UNIVERSAL.



MODERN MILKING SHED IN TARANAKI
BARNs ARE UNNECESSARY IN NEW ZEALAND BE-
CAUSE OF THE MILD WEATHER, AND MILKING IS
GENERALLY CARRIED OUT IN OPEN SHEDS, DE-
SIGNEd TO ACCOMMODATE SIX OR EIGHT COWS.

total population. That is considerably higher than the figure for agricultural states in the United States, but less than the figure for manufacturing states. In Iowa 2 per cent. of the population is engaged in industry. In Minnesota the figure is 3 per cent. Pennsylvania and Ohio each employs 8 per cent. of its population in industry and Massachusetts, 10 per cent.

Of the ninety-six thousand New Zealanders employed in manufacturing, more than three fourths manufacture for home consumption. Fewer than one fourth are engaged in industries manufacturing for export. Almost all those engaged in manufacturing for export are engaged in processing agricultural products: wool, milk, cream, meat and hides. The country is second only to Denmark as an exporter of butter, and is the world's greatest exporter of cheese. She is the biggest supplier of both commodities to the United Kingdom. Hers is the

greatest trade per head of population of any country. She is dependent upon outsiders for: motor vehicles, machinery, metal manufactures and textiles, which together constituted 51 per cent. of the value of imports in 1937.

Of the political, geographic and economic problems facing New Zealand today, none have had more space in the press of the country than the problems of overseas trade.

Financially, the government has, for a good many years, been living on the instalment plan. The government railways, power developments and other beneficial and necessary improvements have been financed by foreign borrowing. Consequently, the country is laboring under a very burdensome foreign debt, one that makes itself felt in every town and village, in every home and in every industry. Payment of interest on that foreign debt uses the value of a large part of the exports every year. Ob-



MANUFACTURING BUTTER, TARANAKI
BUTTER FACTORIES ACCOUNT FOR A VERY LARGE
SHARE OF THE MANUFACTURING IN NEW ZEALAND.
IN THE YEAR 1936-37 THEY PRODUCED ONE
FOURTH OF ALL FACTORY PRODUCTION.



GRAIN HARVEST SHOWN IN THE NORTHERN CANTERBURY PLAINS
GRAIN PRODUCTION IS A MINOR PHASE OF AGRICULTURE IN NEW ZEALAND. THE COUNTRY IS SELF-SUFFICIENT IN ITS GRAIN REQUIREMENTS, ONLY BECAUSE OF STRICT IMPORT REGULATIONS.



SHEPHERD WITH A SMALL "MOB" OF SHEEP NORTH OF NAPIER
SHEEP DOMINATE DRIER EASTERN AREAS. WOOL AND MUTTON ARE EXPORTED AND THE FORMER IS ONE OF THE CHIEF EXPORTS OF THE COUNTRY. DURING MOST YEARS THE VALUE OF WOOL EXPORTED APPROXIMATES THE VALUE OF BUTTER EXPORTED.

viously, the more export value used to pay interest and to reduce the principal of the debt, the less value there will be available to pay for import goods.

In a recent broadcast, Mr. Walter Nash, the Minister of Customs, made the following explanation to his people:

Granted that New Zealand was short of sterling funds, the question was: What was the best way of meeting this position in the interests of New Zealand? We had a certain amount on interest to pay on our debts, a certain amount of capital to be repaid from Government and

Yet we were in a position where we had not sufficient overseas money to pay for the goods which this demand would need. The advice given by some sections of the community was that the Government should cut down public works, cut expenditures, retrench on social services and generally repeat the procedure adopted in past years. This means that these people were advising that thousands of men should be put out of work, that their families should suffer, that those who need social security should do with less, and that generally the poorer paid section of the community should bear the burden of what is a national problem, namely, the cut-



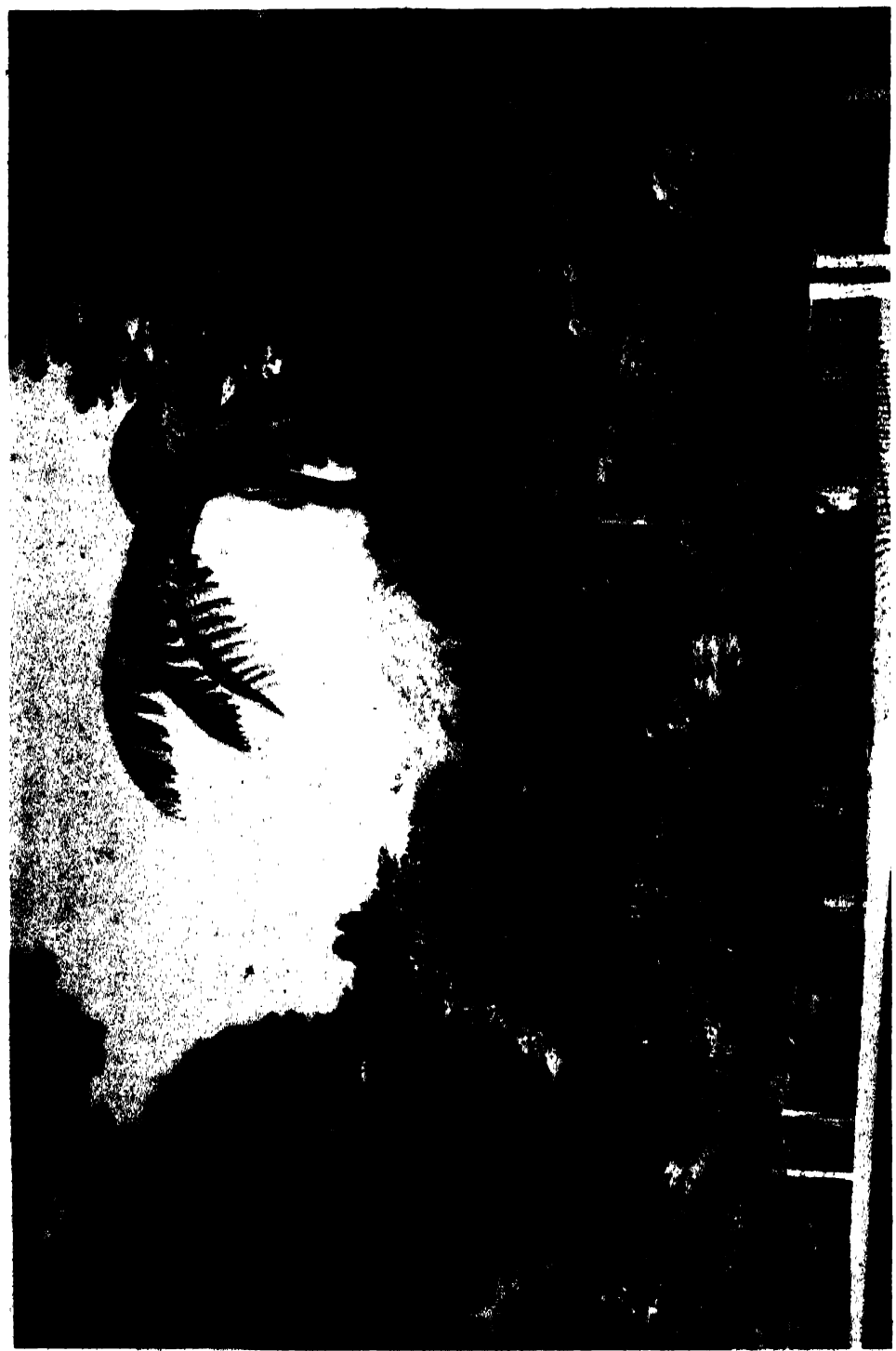
WHEAT PRODUCTION ON FERTILE SUB-HUMID CANTERBURY PLAINS
THIS SMALL AREA PRODUCES ALMOST ALL THE GRAINS FOR THE WHOLE OF THE DOMINION AND IS ABOUT THE ONLY PLACE IN NEW ZEALAND WHERE ANNUAL TILLAGE OF THE SOIL IS COMMON.

local body debts. These had to be paid—there was never any question that they would not be. There was a certain amount left over for imports. That means that no matter what system had been devised, it would have been impossible to pay for any more imports than had been paid for this year (1939).

But in the main people in New Zealand were in employment: they were getting more reasonable wages: their spending power was increased. They still wanted the same amount of goods, the same purchases in the shops, and so the shops demanded of wholesalers and manufacturers the same amount of goods. This meant that manufacturers and importers were demanding the same amount of raw material and finished goods.

ting down of imports. The Government refused emphatically to adopt this course. Accordingly it worked out a system of keeping imports within our capacity to pay for them, but which was not based on cutting wages or retrenching on public works. This procedure has been called the import selection policy.

The government decided that if imports were to be cut, then it would choose which ones were to come into New Zealand: it would choose the more essential ones instead of cutting everything by some fraction, whether it was an important or an unimportant commodity. The Government decided that some things would be allowed in unrestricted, while other things not so important would be cut down some more.



Courtesy Frances Ritchie

CHARACTERISTIC SUB-TROPICAL VEGETATION IN PUKEKURA PARK

During the five-year period 1933-1937 merchandise and specie exports accounted for 92 per cent. to 94 per cent. of the country's overseas credits. On the other hand, imports accounted, during the same years, for less than 70 per cent. of the overseas debits. In each of those years payments on interest and principal, mostly interest, required more than 21 per cent. of the value of the total foreign credits. In other words, more than one fifth of the exports were used to pay interest on the cost of goods which had been imported long ago.

Disregarding the fact that much of the indebtedness was incurred in establishing vital capital goods in the country, the fact remains that New Zealand is a debtor nation with rather extravagant tastes in matters of import goods. New Zealanders travel extensively. They know quality goods, and have been subjected to pressure salesmanship from nations wishing to provide New Zealand's imports. Increased local prosperity since 1935 after a period of depression caused even greater demand for import goods—quite in excess of the value of exports after the necessary interest payments had been deducted. The situation became so serious that the government found it necessary to institute direct import and export control in December, 1938.

The import restrictions particularly have had a tremendous effect upon the everyday lives of all the citizens. American cereals, canned goods, coffee, cigarettes, tobacco and many articles of clothing were wiped off the import list completely. Washing machines, electric refrigerators, cameras (just to mention a few luxury and semi-luxury goods) are permitted only when one can prove an absolute need. It is not possible to import anything without an import license. Furthermore, one must secure the authority of the Bank of New Zealand

before any money or credits can be sent out of the country in payment for import goods or for any other purpose. Possession of an import license does not imply the right to use New Zealand credits in payment for imports. Importing goods and paying for them are two separate and distinct matters and each must have the specific authorization of a different governmental department before it becomes valid and legal.

In addition, export control requires that the overseas credits arising from the sale of goods must be sold to a New Zealand bank in exchange for New Zealand currency. Thus the government acquires control of all new overseas credits whether of public or private origin.

Aside from the effects of this kind of control upon the people of the country, there is another effect of greater significance in the realm of international politics. The government has in its hands a device by means of which it can efficiently but unobtrusively guide the directions of overseas traffic flow. That those who hold this device know of its value and apply it is evidenced by another excerpt from Mr. Nash's radio speech quoted above:

We are purchasing from England as much as we have money to pay for, and we are buying a bigger proportion of our needs in England under this import selection policy. This year the government is spending much more money on defence equipment and some millions of pounds had to be set aside to buy these goods. This means that we can purchase less of other goods. Summed up, the import selection policy enables New Zealand to keep its people in employment, it enables us to build secondary industries rationally, it enables us to give more trade to England, and it enables us to make ample provision for the payment of interest on our debt.

Since London holds most of New Zealand's notes, it is natural that the debtor should try to direct as much of her trade in that direction as possible. The fact

that Britain is the greatest market for New Zealand goods adds another excellent reason for that practice. Tariffs have always favored the United Kingdom over other competitors for the New Zealand market; but in many items the United States, Canada and others have been able to create a worthwhile business in spite of heavy duties. Application of the new device, import and export licensing, has practically eliminated Britain's competitors from the field.

The effects of these restrictions upon the country internally are hard to forecast. It can hardly be denied that an at-

tempt to live within her world trade income and to pay her debts are commendable ambitions. The necessarily rapid readjustments of commerce and industry within the country may cause some severe temporary difficulties. But the natural resources are fair and the cultural resources are superior. A century of experience in isolation has educated the people in the need for initiative and for sacrifice in the face of difficulties. In spite of present economic dependence on her mother country, New Zealand revels in the privileges of independent national character born of her natural location.

CONTRIBUTION OF SCIENTISTS TO NATIONAL DEFENSE

THE first way in which the institute (Massachusetts Institute of Technology) responded to the national emergency was to release experts from its staff to serve in various operating or advisory agencies of the government. Nearly two hundred officers and members of our staff are now engaged in this type of service. Those in this group whose salaries continue to be paid by the institute contributed during the past year approximately fifty thousand man-hours of time to defense, and the others have been temporarily transferred to governmental pay rolls, usually requiring new substitute staff appointments to carry the teaching loads which they have temporarily relinquished.

As the nation's gigantic defense program got under way it quickly became evident that the supply of men with an engineering type of training was very inadequate. Consequently, last October Congress appropriated \$9,000,000 to finance an engineering defense training program to be conducted in qualified colleges under the auspices of the United States Office of Education. The institute has participated in this program by offering during the second term of last year and this past summer twenty-seven intensive tuition-free courses of college or post-graduate grade, with an enrolment of 929 students. . . .

The instruction in this program was given by ninety-four instructors, of whom eighty-one were from the regular staff of the institute. These

instructors carried this program as an addition to their normal institute work. The funds, provided by the Office of Education, totaled approximately \$128,000, which covered salaries, instructional material and supplies, maintenance and repair of equipment used in the courses and the purchase or rental of equipment. The basic financial policy of this engineering defense training program of the United States Office of Education is to reimburse the cooperating colleges for all direct out-of-pocket expenses, but with no allowance for overhead. . . .

Apart from this special defense training program under the Office of Education, we are engaged in a variety of other types of defense training. The Navy continues to send us a group of Naval officers for graduate study, and of the sixty officers who were detailed here last year, forty studied naval construction and naval engineering and the remainder took special work in meteorology, electrical engineering, mechanical engineering or aeronautical engineering.

Last summer a special intensive course in meteorology was given to recruits for the Army Air Corps, and during the past academic year another group of approximately sixty post-graduate students came for training for the Army Air Corps and the United States Weather Bureau. This course is now being repeated for a considerably enlarged group.—*Report of the President, Massachusetts Institute of Technology.*

STRUCTURE OF THE COTTON FIBER AS REVEALED BY THE MICROSCOPE

By Drs. CHARLES W. HOCK and ROBERT C. RAMSAY

RESEARCH ASSOCIATES OF THE TEXTILE FOUNDATION, NATIONAL BUREAU OF STANDARDS

COTTON fibers originate as single-celled outgrowths of epidermal cells of the seed coat. The first evidence of their formation is the appearance on the day of flowering of a swelling on the outer wall of the epidermal cells. The tubular outgrowths thus formed elongate rapidly for a period of 15 to 20 days, when growth in length ceases. During this stage of growth only a thin *primary wall* encloses the protoplasm of the cotton hair. Thereafter the thickness of the wall is increased by a deposition of cellulose which comprises the *secondary wall*. The latter is laid down on the inside of the primary wall, thereby decreasing the size of the central cavity which contains the living protoplasm. Secondary thickening continues until the boll opens, when the exposed hairs dry up and die. Thus, a mature cotton fiber is a single cell, usually more than a thousand times longer than it is wide, and attached to the seed only by its base. Although less than a thousandth of an inch in diameter, a fiber may attain a length of several inches.

In discussing the structure of the cell wall of the cotton fiber it is essential to differentiate between the primary and the secondary wall.¹ Since deposition of the latter does not start until from 15 to 20 days after the fibers originate, young fibers are ideal for studying the structure of the primary wall. When a young fiber is examined microscopically with

¹ Substances which exhibit different indices of refraction along different axes are said to show double refraction or birefringence. One of the best ways for observing the optical properties of birefringent materials is to examine them with crossed nicols, which are prisms employed for polarizing light.

ordinary light there is no evidence of structure in the thin primary wall. On examination with crossed nicols,¹ however, the fibers show a low order of birefringence, with colors indicative of a predominantly transverse orientation. After treatment with cellulose dyes the fibers give a faint color reaction, and upon examination with crossed nicols appear distinctly birefringent. This increase in birefringence upon staining is due, apparently, to the double refraction of the dye molecules which are preferentially adsorbed by the small amount of cellulose in the primary wall. When the stained primary wall is placed between crossed nicols so as to show its maximum brightness the cellulose is found to be present as crisscrossing strands which have a netlike appearance (Fig. 1). The reticulate structure of the cellulose in the primary wall appears to become coarser and to show greater birefringence as the wall increases in age.

Cellulose is not, however, the chief constituent of the primary wall. The

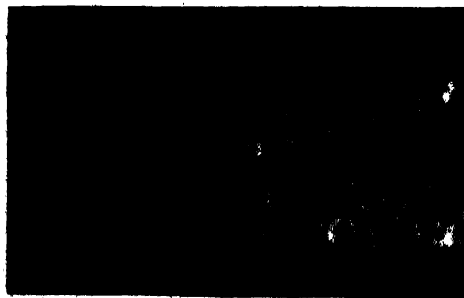


FIG. 1. FIFTEEN-DAY COTTON FIBER STAINED WITH CONGO RED AND PHOTOGRAPHED BETWEEN CROSSED NICOLS TO SHOW STRANDS OF CELLULOSE IN PRIMARY WALL. $\times 672$.

latter also contains wax and pectic materials which may be detected by applying various stains to the fiber, as well as by direct chemical analysis. When young fibers are purified by the removal of wax and pectin the delicate framework of cellulose always remains. It appears, therefore, that the primary wall is made up of a tenuous network of cellulose strands intimately associated with a membrane of wax and pectic substance. Although it comprises only a relatively small part of a mature cotton fiber, the primary wall greatly influences the surface properties of the fiber which play a prominent rôle in dyeing, finishing and other processing of cotton.

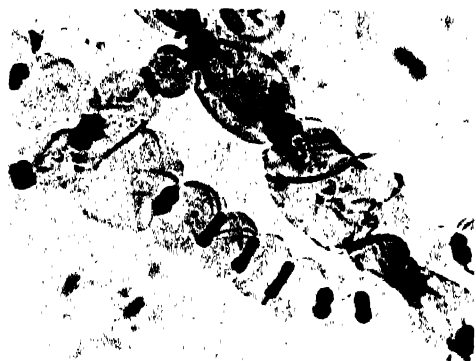


FIG. 2. MATURE COTTON FIBER IN CUPRAMMONIUM HYDROXIDE SOLUTION, SHOWING IRREGULAR SWELLING DUE TO CONSTRICTING INFLUENCE OF PRIMARY WALL. $\times 95$.

The principal chemical constituent of cotton, and the one chiefly responsible for its usefulness to man, is cellulose. The bulk of the cellulose of a cotton fiber is in the secondary wall. Because it is a more favorable medium for study, and also because of its greater economic importance, the attention of most investigators has been directed mainly to this part of the fiber. As a result, much more is known about the structure and behavior of the secondary wall than is known about the primary wall.

Cuprammonium hydroxide solution is frequently employed, commercially as

well as in the laboratory, as a solvent for cellulose. The reagent was first used nearly one hundred years ago by Schweizer, who made some interesting observations on the behavior of plant cell walls in this solution. When mature cotton fibers are placed in cuprammonium reagent they immediately begin to swell and twist. The rapid expansion of the cellulose of the secondary wall often results in the rupture of the primary wall. As the cellulose continues to push through such a break, expanded regions resembling beads appear along the axis of the fiber (Fig. 2). Where these expanded areas occur close together the fiber has an appearance resembling a string of pearls. After a short time, however, the cellulose dissolves completely, leaving a residue which consists principally of fragments of the primary wall, and to a lesser extent of material from the central cavity or lumen.

Full-strength cuprammonium reagent dissolves the cellulose of single cotton fibers or of cross sections in a relatively short time. Dilute solutions of the reagent, on the other hand, swell the fibers greatly but dissolution of the cellulose is retarded. Swelling fibers in this way offers an excellent means of observing details of their structure. When cross sections of cotton fibers are treated with dilute cuprammonium hydroxide solution the sections swell to many times their original diameter, thereby revealing a layered structure. On treating the swollen sections with a dye such as Congo red, alternating layers appear to stain deeply and lightly with the dye (Fig. 3, A and B). Between crossed nicols these sections show alternating layers of strong and weakly birefringent material (Fig. 3, C). The layered structure of the secondary wall can also be observed in longitudinal view (Fig. 4), where stripes running parallel to the fiber axis, and extending from the lumen to the primary wall, can be seen. The first

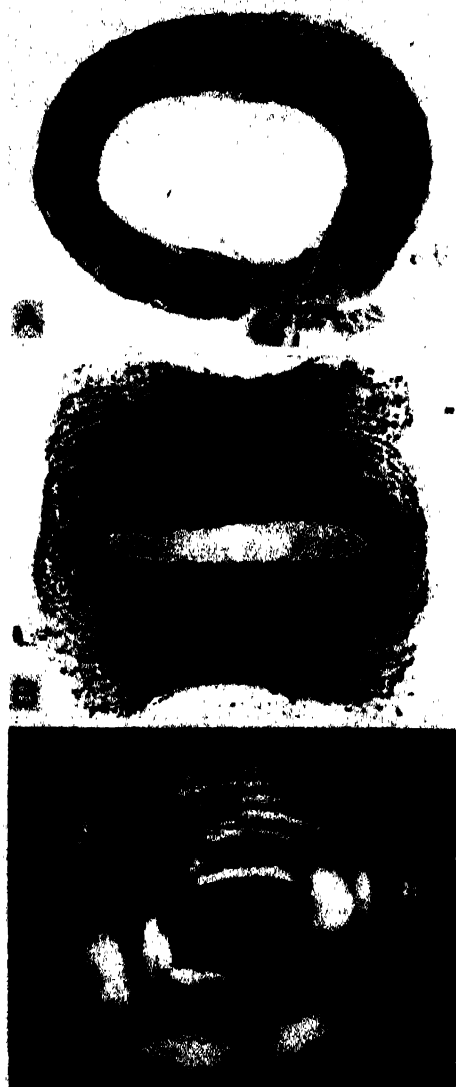


FIG. 3. CROSS SECTIONS OF FIBERS COTTON FIBERS SWOLLEN IN CUPRAMMONIUM HYDROXIDE SOLUTION TO SHOW THE LAYERED STRUCTURE OF THE SECONDARY WALL. A. SECTION OF AN IMMATURE (25-DAY) FIBER. MAGNIFICATION $\times 811$. B. SECTION OF A MATURE FIBER FROM AN OPEN BOLL. MAGNIFICATION $\times 863$. C. SECTION OF A 26-DAY FIBER PHOTOGRAPHED BETWEEN CROSSED NICOLS. MAGNIFICATION $\times 600$.

layer is laid down on the day when secondary thickening is initiated, the num-

ber increasing thereafter as the fiber approaches maturity. This increase in the number of layers with increase in age of the fiber can be seen by comparing Fig. 3, A with Fig. 3, B.

It has been shown that two adjacent layers, one compact and one porous, are deposited every twenty-four hours during the period of secondary wall deposition. Two adjacent layers together constitute, therefore, a daily "growth ring." The denser of the two layers which com-



FIG. 4. LONGITUDINAL VIEW OF FIBER SHOWING THE LAYERS IN THE SECONDARY WALL OF A SWOLLEN 51-DAY FIBER. $\times 500$.

prises each ring was found to be laid down during the day, the other at night. Counts of rings in fibers of different ages indicate that after the start of secondary growth, one ring is laid down per day until the fiber reaches maturity. The width of individual growth rings varies from one to five microns.² The width of

² A micron is approximately one twenty-five thousandths of an inch.



FIG. 6. A SINGLE SWOLLEN FIBER BEING DISSECTED WITH MICRO-NEEDLES TO SHOW ITS FIBRILLAR STRUCTURE. MAGNIFICATION $\times 625$.

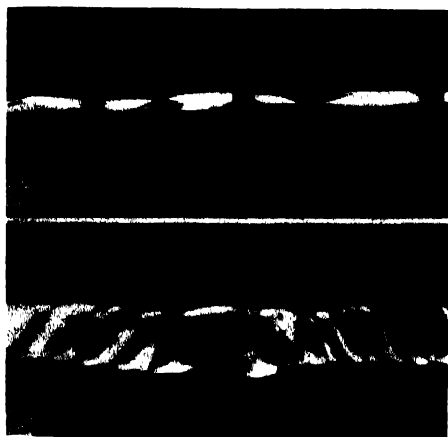


FIG. 5. MATURE FIBER AND SLIGHTLY SWOLLEN FIBER

A. MATURE FIBER MOUNTED IN WATER AND PHOTOGRAPHED BETWEEN CROSSED NICOLS TO SHOW THE BANDS OF EXTINCTION WHERE THE FIBRILLAR ORIENTATION REVERSES. MAGNIFICATION $\times 144$. B. A SLIGHTLY SWOLLEN FIBER, PHOTOGRAPHED BETWEEN CROSSED NICOLS TO SHOW A REVERSAL IN THE DIRECTION OF ORIENTATION OF THE FIRST LAYER OF FIBRILS DEPOSITED IN THE SECONDARY WALL. MAGNIFICATION $\times 420$.

the rings appears to fluctuate with variations in environmental conditions. For certain localities at least, variations in temperature and the width of the growth rings can be correlated. Thus, cotton fibers from different plants, but grown under the same conditions, show similar rings, so that it is possible to cross-date daily growth rings of cotton just as annual rings are cross-dated in the trunks of certain trees.

Upon examination of single cotton fibers with crossed nicols much can be learned about the orientation of the cellulose. When the fibers are placed approximately parallel to the plane of light passing through one of the nicol prisms, the high birefringence of the fibers is interrupted by dark extinction bands at irregular intervals along the axis (Fig. 5, A). These optical variations can be correlated with differences in structure observed in slightly swollen fibers. Upon swelling, the latter clearly reveal a fibrillar structure. The bulk of

the fiber is made up of innumerable fine fibrils oriented at an acute angle with respect to the axis of the fiber. The fibrils make either an "S" or "Z" twist,* reversal of direction (Fig. 5, B) taking place many times in a single fiber.

It appears also that, at least in certain types of cotton, the direction of orientation of the fibrils in the first-formed layer is opposite from that in layers which are laid down thereafter. In other words, if the first layer of fibrils makes an "S" twist, all the fibrils formed in subsequent layers make a "Z" twist.

It is readily apparent that reversals of direction of the cellulose fibrils are responsible for the optical differences observed with crossed nicols, and that the band of extinction is the place at which the reversals occur. It can be shown that the number of extinction bands in a single fiber invariably corresponds with the number of fibril reversals.

In carrying out microscopic investigations of this sort, the question often arises whether the structures which are seen are real. For example, are the apparent fibrils which may be observed under various conditions of illumination, real structures or are they due merely to surface irregularities or diffraction phenomena? To aid in answering such questions a micromanipulator can be of great help. This instrument makes possible the precise mechanical control of fine glass needles (about 0.0001 inch wide

*The fibrils are said to show an S twist if, when the fiber is held in a vertical position, the spiral of the fibrils conforms in slope to the central portion of the letter "S" and a Z twist if the spirals conform to the central portion of the letter "Z."

at the tip) whereby fibers can be dissected, flattened, stretched and otherwise handled so as to clarify details. When needles are inserted in the fine fibrils comprising the bulk of the cellulose of the secondary wall the fibrils may be separated from one another (Fig. 6) in a manner which makes it clear that the fibrils are real structures and not artifacts.

The system of fine threads or fibrils which make up the secondary wall are variously grouped so as to give a layered pattern. In an expanded transverse section of the wall the fibrils may be observed as more or less round structures. In the denser layers of the fiber there are, presumably, more fibrils per unit area than in the more porous layers which are deposited during the day.

Microscopic examinations thus make it clear that a cotton fiber, which at first glance may appear to be a relatively simple unit in itself, is in reality made up of still smaller structures upon which the properties of the whole fiber depend. The wall of a mature fiber appears to have the following structure. The secondary wall, which contains nearly all the cellulose of the fiber, consists of innumerable spirally oriented fibrils of exceedingly fine diameter. The secondary wall is enclosed by a thin primary wall which consists of a layer of wax and pectic material associated with a fine network of cellulose. The primary wall covers the secondary wall like a tight sausage casing and exerts a marked influence on the behavior of the fibers. The lumen or central cavity also contains wax and pectic substances, plus various amounts of degenerated protoplasm.

ON THE SOTHIC CYCLE

By Professor WM. A. LUBY

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THE earliest astronomers known left no material evidence of their work. None of their ruined observatories nor their decayed instruments have resisted the course of time. Nor have their records of observations of the heavenly bodies been preserved. Singularly enough the proof of their activity was a calendar which they devised and induced a great country to adopt. That country was Egypt, and the calendar was the famous Egyptian calendar which remained in use for over forty centuries.

Extensive research by various Egyptologists has established numerous interesting facts concerning the Egyptian calendar. In that calendar the year consisted of twelve months of thirty days each and five holidays. This made a year of 365 days. Whether these early scientists knew that the year consisted of about $365\frac{1}{4}$ days or not is unknown. At any rate later Egyptian astronomers discovered that fact, but they did not change their calendar to take care of it.

It is indeed striking that the Egyptian calendar makes no attempt to use the lunar month of 29.5 days. The Babylonians, the Hebrews, the Greeks and the Romans endeavored in various ways to fit the lunar month into the year. One of these ways was to use months of 29 days and 30 days successively. This gave a year of 354 days. So extra months had to be inserted from time to time. The modern value of the lunar month 29.531 days and the tropical year 365.2422 shows the impossibility of an attempt to make one fit into the other.

The Egyptian year had three seasons called the Inundation, the Cultivation

and the Harvest. The first season of the year shows by its name its relation to the annual rise of the Nile. At first, New Year's day was closely associated with one astronomical phenomenon, namely, the rising of the star Sirius just before the sun. This is the so-called heliacal rising of Sirius.

Egyptologists believe that the calendar agreed with the sun at the start. But in four years, the calendar would be in error by one day. In eight years, the error would be about two days. In 120 years the error would be approximately 30 days. As time passed the seasons would shift farther from their original place. Winter would come in the summer months and *vice versa*. Eventually the calendar would once more agree with the seasons and the annual rise of the Nile would again nearly agree with the first day of the year.

The Egyptian name of Sirius is Sothis. Hence the interval required for the seasons to shift through the year was called the Sothic cycle. According to the calculations of the time this was 1,460 years. This number is obtained by dividing 365 by one fourth.

Now the Egyptian calendar was used down to relatively modern times. According to Censorinus, a Latin writer, Sirius rose just before the sun in 139 A.D. This means that New Year's day in the civil calendar of Egypt once again agreed with the heliacal rising of Sirius. Counting back intervals of 1,460 years gives the dates 1318 B.C., 2781 B.C. and 4241 B.C. In his earlier work, Breasted gives 4241 B.C. as "the earliest recorded date in history." ("Ancient Times,"

page 45). Accordingly, the Egyptian calendar was put into effect on July 19, 4241 B.C.

In an article in the October number of *THE SCIENTIFIC MONTHLY* for 1935, Breasted gives the intervals 1318 B.C., 2776 B.C. and 4236 B.C. The reason for these slight differences need not concern us here. According to Dawson "the great majority of Egyptologists are in favor of the earlier of the last two dates, as the one on which the Egyptian calendar was inaugurated" ("The Age of the Gods," page 151). The Cambridge Ancient History is in substantial agreement with Breasted (Volume I, page 168). Meyer, in "Geschichte des Altertums" is in good agreement with both. He, however, uses 1,461 years, not 1,460, as the Sothic cycle (Volume I, page 109). This number is obtained by dividing $365\frac{1}{4}$ days by one fourth.

Whether the Egyptian calendar was inaugurated in about the year 2776 B.C. or in about 4236 B.C. is a matter for the Egyptologists to determine on the basis of the evidence. With that question the writer is not concerned. He does, however, wish to point out that the historians referred to have incautiously used an erroneous value for the length of the Sothic cycle. Hence each date determined by means of it is in error.

The matter is not determined by what the Egyptians thought the length of the Sothic cycle was. Newcomb, in his "Popular Astronomy," pages 47-48, writes: "After the lapse of 1,460 years,

according to the calculations of the time, each season would have made a complete course through the twelve months, and would have then returned once more to the same time of year as in the beginning. This was termed the Sothic period; but the error of each year being estimated a little too great, as we now know, the true length of the period would have been about 1,500 years."

The length of the solar year is 365.2422 days. If we divide this by .2422, the result is approximately the length of the Sothic cycle or 1508. + years. But the length of the year is changing. At the present time it is decreasing one second in 200 years. In the course of time it will increase again. The length of the day also appears to be variable. Hence after the lapse of many years the Sothic cycle itself changes slightly. Its length, however, is near 1,500 years, the value given by Newcomb.

Since a Sothic cycle of 1,460 years was applied three times previous to 139 A.D. the result given by Breasted is in error by at least three times the difference between 1,500 and 1,460 or 120 years. This gives $4236 + 120 = 4356$ B.C. This makes "the earliest recorded date in history" July 19, 4356 B.C. If the Sothic cycle, during the last 60 centuries, remained nearly constant at 1,508 years, the error would be about 144 years instead of 120. Apparently the Egyptian calendar was put into effect on July 19 in a year near or one somewhere within the interval from 4356 B.C. to 4380 B.C.

INVENTIONS AND WAR

By Dr. QUINCY WRIGHT

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THROUGHOUT the long history of war, there has been a cumulative development of military technology. Invention of defensive instruments has usually followed close on the heels of the invention of offensive weapons.¹ This balance of technology has tended to support a balance of power. But the balance has not tended toward increasing stability, consequently the political effect of military invention has not been continuous. There have been times when inventions have given the offensive an advantage and conquerors have been able to overcome the defenses of their neighbors and build huge empires. At other times the course of invention and the art of war have favored the defensive. Local areas have been able to resist oppression, to revolt and to defend themselves from conquest. Empires have crumbled, local liberties have been augmented and international anarchy has sometimes resulted.

During the last five centuries, military invention has proceeded more rapidly than ever before. Important differentials in the making and utilization of such inventions have developed. In general, the inventions have favored the offensive, and there has been a tendency for the size of political units to expand. This tendency was, however, arrested during much of the nineteenth century by inventions favoring the defensive and many self-determination movements were successful. This article will trace the development of modern military technique as influenced by invention, the outstanding characteristics of that tech-

nique at the present time, and its present and potential political effects.

1. DEVELOPMENT OF MODERN MILITARY TECHNIQUE

"Until within the last few years," wrote Rear Admiral Bradley A. Fiske in 1920, "the most important single change in the circumstances and methods of warfare in recorded history was made by the invention of the gun; but now we see that even greater changes will certainly be caused by the invention of the airplane."² Modern civilization began in the fifteenth century with the utilization of the first of these inventions and has witnessed the steady improvement of this utilization through development of accuracy and speed of fire of the gun itself; penetrability and explosiveness of the projectile; steadiness, speed, and security of the vehicle which conveys it over land or sea toward the enemy; discipline and adaptation to such utilization of military organizations.

While the airplane continued this development by providing an even swifter vehicle for carrying the gun, it also introduced the third dimension into warfare, permitting the use of gravitation to propel explosives, far wider and more accurate scouting, and an extension of military action behind the front, over vast areas and across all barriers of terrain. Both of these inventions, after their use was thoroughly understood, greatly augmented the power of the offensive, though, in the case of the gun the defense immediately began to catch up and the general trend of war between

¹ "The Art of Fighting," New York, 1920, p. 361; see also Lewis Mumford, "Technics and Civilization," New York, 1934, p. 37.

² This perhaps supports S. C. Gilliland's insistence that inventions are usually made in response to a need. ("The Sociology of Invention," Chicago, 1935, pp. 10, 152.)

equally equipped belligerents was toward a deadlock.³ A similar tendency is already observable in the case of the airplane.

The history of modern military technique falls into four periods, each initiated by certain physical or social inventions and leading to certain military and political consequences—the periods (a) of experimental adaptation of firearms and religious war (1420–1648), (b) of professional armies and dynastic wars (1648–1789), (c) of industrialization and nationalistic wars (1789–1914), (d) of the airplane and totalitarian war (1914–).

(a) During the period of discoveries and wars of religion, medieval armor was being abandoned, pikemen, halberdiers and heavy cavalry were going, and the Turkish Janissary infantry, equipped with cutlass and long bow, well-disciplined and supported by light cavalry and artillery, were being copied throughout Europe. Heavy artillery had been able to reduce feudal castles and the “wagenburg” had revolutionized field tactics. The experience of the Thirty Years’ War (1618–1648) ended this period of experimental adaptation of firearms by mercenary armies, and modern armies began to emerge.⁴

Naval architecture was greatly improved during this period. The clumsy galleons of the Spanish Armada, differing little from those of Columbus a century earlier, and resembling the oar-propelled galleys of the Middle Ages, were superseded in the mid-seventeenth century by longer, swifter and more heavily armed “broadside battleships” which differed little from those of Nelson, nearly two centuries later.⁵

³ Flake, *op. cit.*, p. 355.

⁴ Charles Oman, “A History of the Art of War in the Sixteenth Century,” London, 1937; Spaulding, Nickerson and Wright, “Warfare,” London, 1934.

⁵ S. C. Gilliland, “Inventing the Ship,” Chicago, 1935. The beginnings of this type were to be found in the ships with which Drake and Hawkins fought the Armada.

Equipped with the new technique of firearms, Europeans had occupied strategic points in America, Africa and Asia, readily overcoming the natives whom they encountered. The tendency of this new technique was toward political integration inside and expansion outside of Europe. By increasing the relative power of the offensive, firearms made it possible for the more aggressive rulers, especially those of Turkey, Portugal, Spain, France, Britain, Prussia, the Netherlands and Sweden, to expand their domains in Europe at the expense of feudal princes and to expand overseas at the expense of native chieftains.

(b) The seventeenth and eighteenth centuries witnessed the development of the professional army, loyal to the king and ready to suppress internal rebellion or to fight foreign wars if paid promptly, and if the officers were adequately rewarded by honors and perquisites of victory. Louis XIV and Cromwell contributed greatly to the development of this type of army, which, however, in the eighteenth century tended to be more concerned with safety and booty than with victory. Consequently, military invention emphasized defense and fortification. The art of war prescribed elaborate rules of strategy and siegecraft. Rules also dealt with the treatment of prisoners, with capitulations, with military honors and with the rights of civilians. The Prussian army with its vigorous discipline, aggressiveness and new strategic ideas under Frederick the Great to some extent broke through this defensive technique and brought this type of army to the highest point.⁶

The destructiveness of war was limited by the general exemption from the activities of land war of the bourgeois and the peasants, who constituted the bulk of the population. The bourgeois

⁶ G. N. Clark, “The Seventeenth Century,” Oxford, 1929; Spaulding, Nickerson and Wright, *op. cit.*; John W. Wright, *American Historical Review*, July, 1934, pp. 629 ff.; Richard Lewinsohn, “The Profits of War,” pp. 28 ff.

were anti-military in attitude and of little influence in the politics of most states. The monarchs preferred to leave their own bourgeois and peasants to production, provided they paid taxes, and to recruit their armed forces from the unproductive riffraff, officered by the nobility, whose loyalty could be relied upon. With the existing techniques their armies could not easily attack the enemy's middle classes, unless his army was first destroyed and his fortifications taken. In that case such attack was unnecessary because these classes would usually accept whatever peace might be imposed. Lacking in patriotism or nationalism, they were little concerned if the territory on which they lived had a new sovereign provided they could retain their property.⁷

Navies reached the limit in size possible for wooden ships in the seventeenth century and underwent very little change until the steel ship developed 250 years later. The problem of adequate raw materials for war instruments was sharply presented in England during the latter part of this period as a shortage of oak for the hull beams, and of huge pines for the masts developed. The United States profited in the Revolution by blocking the British from their Canadian supply of mast timber. The British never met this problem by a consistent policy of planting until after the Napoleonic Wars, when the oaks were planted too late to become ripe until wood was superseded by steel in shipbuilding.⁸

(c) The French revolutionary and Napoleonic period developed the idea of the "nation in arms" through revolutionary enthusiasm and the conscription of mass armies.⁹ The idea of totalitarian

war was developed in the writings of Clausewitz, rationalizing Napoleonic methods. After these wars, the issue between professional, long-service, aristocratically officered armies and conscript, short-service, democratic armies was debated on the continent of Europe with a general relapse to the former type during the long peace of Metternich's era. The rise of nationalism, democracy and industrialism, and the mechanization of war in the mid-century reestablished the trend toward the nation in arms and totalitarian war.¹⁰

The use of steam power for land and water military transportation developed in the first half of the nineteenth century and was given its first serious test in the American Civil War. Moltke appreciated the military value of these inventions and his genius in using railroads for rapid mass mobilization won Bismarck three wars with extraordinary rapidity against Denmark, Austria and France. The ironclad and heavy naval ordnance were also tested in the American Civil War. The era of military mechanization progressed rapidly, adding greatly to military and naval budgets and to the importance of national wealth and industry in war. The new methods were given a further test in the Spanish-American, Boer, and Russo-Japanese wars.

The great nineteenth century naval inventions—steam power, the screw propeller, the armored vessel, the iron-hulled vessel, heavy ordnance—were at first favorable to British maritime dominance because British superiority was more marked in iron and coal resources and a developed heavy industry than in forests and wooden shipbuilders. But this advantage did not continue. The new battleships were more vulnerable than the wooden ships because ordnance gained in the race with armor, and re-

⁷ Hans Speier, *Social Research*, 1936, vol. 3, pp. 304 ff.

⁸ Robert C. Albion, "Forests and Sea Power," "The Timber Problem of the Royal Navy, 1652-1862," Cambridge, 1926.

⁹ Hoffman Nickerson, "Can We Limit War?" Bristol, 1933, pp. 111 ff.

¹⁰ A. F. Kovacs, "Prussian Military Legislation," Manuscript Thesis, University of Chicago, 1934.

pair at sea was impossible. Furthermore, the mine, torpedo, submarine and airplane added new hazards to the surface fleet, especially in the vicinity of the enemy's home bases. Warships, therefore, became more dependent upon well-equipped and secure bases for fueling and repair, and approach to even a greatly inferior enemy became hazardous. With the industrialization of other powers and their development of naval strength, Britain found it increasingly difficult to maintain a three or even a two power superiority in the ships themselves, while their distant bases became less secure.¹¹

Britain abandoned the effort to dominate the Caribbean after the Venezuelan controversy with the United States in 1896, acquiesced in American seizure of the Spanish islands and agreed to an American fortified Panama Canal. It also welcomed American acquisition of the Philippines and in 1902 made an alliance with Japan, indicating doubt of its capacity to maintain its Far Eastern position by its own forces. The entente with France indicated awareness that British Mediterranean interests could no longer be defended single-handed.

Britain thus recognized that the development of naval techniques had tended toward a regionalization of sea power, and as a result it reduced its commitments for unilateral sea control from the seven seas to those seas controllable from bases on the British and Portuguese isles and from Gibraltar, Suez and Singapore. The far-flung British empire, the highways of the Mediterranean, the Caribbean and the China Sea and the Pacific could no longer be defended by the British navy alone. They must be defended by the

dominions themselves and by alliances and friendships, especially with the United States, France and perhaps with Japan. It was clear that the British capacity to maintain reasonable order, respect for law and commercial obligations, and to localize wars by maintaining the balance of power in Europe had been greatly reduced. Naval inventions and the spread of industrialization had ended the Pax Britannica.¹²

This situation was realized by the continental powers, who developed their armies and navies with increasing speed after observation of the Russo-Japanese war, and after the failure of the Hague Conferences to achieve disarmament. They paid particular attention to the potentialities of the improved rifle, machine gun and artillery, as well as to the art of entrenchment.¹³ The possibilities of the mine, torpedo and submarine were developed, especially by France, pointing the way for German utilization of these weapons in the World War. Beginnings were made, especially by France and Germany, in the adaptation of the airplane and dirigible to military purposes. The results anticipated by the Polish banker, Ivan Bloch, in his book written in 1898, occurred. War became deadlocked in the machine gun lined trenches, in the mined and submarine infested seas of the World War. This deadlock was not broken until attrition had ruined all the initial belligerents, and new recruits and resources on the Allied side from the United States made the cause of the Central Powers hopeless.¹⁴

¹² Q. Wright, *American Journal of International Law*, July, 1940, vol. 34, pp. 410 ff.

¹³ Lt. Col. Asan, "The War of Position," Cambridge, 1917. Introduction; Admiral Fiske, *op. cit.*, pp. 355-59.

¹¹ J. P. Baxter, "The Introduction of the Ironclad Warship," Cambridge, 1933; Bernard Brodie, "Major Naval Inventions and Their Consequences in International Politics, 1814-1918," Manuscript Thesis, University of Chicago, 1940.

¹⁴ While the capacity for coordination which was perhaps greatest in Germany because of her discipline and the fact that she had the interior lines, and least for Russia among the great powers, accounted for the prior breakdown of the latter, the quantity of resources to draw upon,

The advent of aerial war in the twentieth century ended the relative invulnerability of the British Isles to invasion. The weakening of surface control of the sea by the use of mines, submarines and airplanes further impaired the position of Great Britain and that country during the 1920's accepted the thesis that the integrity of the empire depended upon collective security. The possibilities of the airplane and tank, neither of them fully exploited during the World War, supported hope in some quarters and fear in others that the power of the offensive would be increased, that mobility in war would be again possible, and that the deadlock would be broken.¹⁵

These possibilities encouraged aggression by Japan, Italy and Germany after 1930. Dissatisfaction with the political results of the first World War, resentment at the self-centered economic policies of the democracies, serious deterioration of the middle classes and the spread of revolutionary ideologies engendered by the costs of war, widespread unemployment flowing from the great depression of 1929 provided motives for aggression

which was less for Germany than for her enemies who held the exterior lines, accounted for Germany's ultimate defeat. The discouraging influence which quantitative comparisons must have had on the German command after American entry into the war can be appreciated by a study of the data in Leonard Ayres's statistical summaries "The War with Germany, a Statistical Summary," Washington, 1919.

¹⁵ General Douhet of the Royal Italian Air Force seems to have initiated the idea (of obvious propaganda value to a state planning to expand by military bluffs, whatever its military value) that victory can only be won by attack which under modern conditions is only possible by air; that surface defense should be only to facilitate air attack; that adequate air forces can soon gain "command of the air"; that, once gained, this command, if ruthlessly exploited to attack the enemy's big cities, can so break the enemy's morale that he will surrender. (See Lieut. Col. P. Vauthier, "La doctrine de guerre de General Douhet"; Dupuy and Elliot, "If War Comes," 1937, pp. 53, 60; Hart, "The Remaking of Modern Armies," pp. 96 ff.

sions, but if collective security had been better organized and the airplane and tank had not been invented, the prospects would hardly have been sufficiently encouraging to induce action. As it was, the initial success of Japan in Manchuria and the failure of the disarmament conference, alarmed the Soviets into rapid rearmament and encouraged Italy and Germany to do likewise, especially in the air. Initial failure of the democracies to support the treaty structure when Germany began to rearm and to reoccupy the Rhineland in violation of international obligations, encouraged these states to consort together and to continue aggression in weak areas utilizing aviation with rapid success, while all phases of the national life were organized for total war.¹⁶

This development of militarism, totalitarianism and aggressiveness was most completely exhibited in Nazi Germany. Here the reaction from military defeat had been intense, confidence in technical ability to develop mechanized war was great, the economic situation was particularly grave, and the extreme democracy of the Weimar Constitution made government weak. In the background, however, the foundations had been laid by the historic rise of Prussia through war; the methods of the Great Elector, Frederick the Great, and Bismarck; the philosophies of Fichte, Hegel, Nietzsche; the historical interpretations of Mommsen and Treitschke, and the geopolitics of Ratzel and Haushofer.¹⁷ Similar developments had begun in England under Cromwell and in France under Louis XIV and Napoleon at times when new military techniques, the disciplined use of firearms, superior coordination of

¹⁶ Speier and Kähler, eds., "War in Our Time," especially chapter on War Economics by E. Lederer, pp. 48 ff.

¹⁷ F. Schuman, "The Nazi Dictatorship," New York, 1935; J. T. Shotwell, "What Germany Forgot," New York, 1940.

army and industry, mass mobilization through nationalistic propaganda, appeared to give these governments a strategic initiative. The strength of parliamentarism and reliance upon the navy stopped the trend in England, as in France did military defeats, the democratic sentiment of the revolution and the declining population of the nineteenth century. In the United States decentralized institutions, geographic isolation, and the democratic tradition have formed a barrier against militarism. In Japan, Italy and the Soviet Union, however, the circumstances of political ambition, economic frustration, imputations of racial, social or political inferiority, post-war disorganization and revolutionary ideas, when stimulated by hopes born of new military inventions, have tended in varying degrees toward military totalitarianism similar to that of Germany.

As the development of the gun by European great powers in the sixteenth and seventeenth centuries extended their imperial control to the overseas countries, followed by the latter's imitation of their techniques and eventual revolt, so the development of the airplane by the totalitarian states in the twentieth century first extended their empires and then compelled the democracies to adopt their techniques. Thus the great powers, whether with a democratic or an autocratic tradition, whether relying on the army or navy, whether European or American or Asiatic, have in a disorganized world felt obliged to follow the lead of that one of their number most advanced in the art of war.

The trend toward general militarization initiated by the gun was, however, checked in the eighteenth and nineteenth centuries through the rise of the naval, commercial, industrial and financial power of a relatively liberal and anti-military Britain; through the increasing

indecisiveness and destructiveness of war; through the professionalization of the armed forces; and through the anti-militaristic philosophies of the rising bourgeois. It is possible that the position of the United States, the philosophy of peace and international organization, the economic cost of total war and perhaps the failure of aggression in the second world war may have a similar influence in the latter part of the twentieth century. In April, 1940, in spite of the success of Hitler's *Blitzkrieg* in Poland, Denmark and Norway, some military experts were predicting the failure of that method and the entry of the second world war into a long stage of attrition in which the superior morale, control of resources and manufacturing capacity of the democracies and the neutrals trading with them might eventually win the war.¹⁸ It seems probable, however, that small nationalities can no longer defend themselves from powerful neighbors equipped with a vast superiority of planes. As the invention of artillery made it possible for monarchs to batter down feudal castles and build nations, so the airplane will destroy the independent sovereignty of nations and create larger regional units in their place. Whether there will be empires resting on conquest alone or federations resting on consent remains to be seen.

2. CHARACTERISTICS OF MODERN MILITARY TECHNIQUE

(a) The outstanding characteristic in which modern war has differed from all earlier forms of war has been in the degree of mechanization. The use of long-range striking power (rifles, machine guns, artillery, gases), of power-propelled means of mobility (railroads, motor trucks, battleships, tanks, airships), and of heavy protective covering (armor plate on fortresses, tanks and

¹⁸ Stephen King-Hall, *News Letter*, Supplement, 195, April 5, 1940.

warships) has meant that the problem of war manufacture has risen to primary importance.¹⁹ In historic civilizations the soldier provided his own equipment, and it generally lasted as long as the soldier. Some equipment was lost, but even arrows could usually be collected in large numbers from the battlefield. Now a dozen men must be engaged in production and transportation services behind the lines to keep one soldier supplied.²⁰

(b) A second important change has been in the size of armies, both absolutely and in proportion to the population. It might seem that if each soldier needs such a large amount of civilian help there would be fewer soldiers, but this has not proved to be the case. Power transport and electrical communication have made it possible to mobilize and control from the center a much larger proportion of the population than formerly. Men can be transported rapidly by railroad and motor lorry, and canned food can be brought to them. Thus where formerly one per cent. of the population was a large number to mobilize, now over ten per cent. can be mobilized, of which a quarter may be at the front at one time. But ten per cent. mobilized requires most of the remaining adult population to provide them with the essentials for continuing operations. Thus instead of one per cent. engaging

¹⁹ Friedrich von Bernhardi, "On War of Today," London, 1917, vol. 1, chaps. 3, 4; Engelbrecht and Hannighan, "Merchants of Death," New York, 1934, chap. 1. Pecuniary profits of war have shifted from the direct plunder or reward of the general, privateer, soldier and sailor to the indirect gains of the war financier, war trader, war manufacturer, war contractor and war speculator. Richard Lewinsohn, *op cit.*, pp. 115, 300.

²⁰ Adam Smith, "Wealth of Nations," book 5, chap. 1; J. M. Clark, W. H. Hamilton and H. G. Moulton, "Readings in the Economics of War," Chicago, 1918, pp. 98 ff., 112 ff. Hans Speier, *American Sociological Review*, 1939, vol. 4, p. 374.

in war and the rest pursuing their peacetime occupations of trade or agriculture, now over half of the entire population must devote itself to direct or indirect war service.

(c) A third change, consequent upon the second, has been the military organization of the entire nation. The armed forces have ceased to be a self-contained service apart from the general population. The soldiers and sailors must be recruited from those men whose services can be most readily supplied by women, children and the aged. The experts in transportation and industrial services must be largely exempted in order that they may continue their "civilian" services which, under modern conditions, are no less essential to war. Such a gearing in of the agricultural, economic and industrial population to the armed forces requires a military organization of the entire population. Since the perfection of such an organization after the outbreak of war has been impossible, the conditions of war have more and more merged into those of peace. The military organization of the entire population in peace has become necessary as a preparation for war.²¹ The development of modern military technique has, therefore, tended toward the military state.²²

(d) A fourth change, characteristic of modern military technique, has been the extension of government into the control of economy and public opinion. The military state has tended to become the totalitarian state. Other forces of modern life have, it is true, had a similar tendency. Democracy, under the influence of nationalism, has induced the individual to identify all phases of his life with that of the state, while state socialism, under the influence of depression,

²¹ Hans Speier, *loc. cit.*; Frieda Wunderlich, *Labor in War Time*, in Speier and Kähler, eds., *op. cit.*, pp. 245 ff.

²² Hans Speier, *Social Research*, 1936, vol. 3, pp. 304 ff.

has induced the state to intervene in all phases of the life of the individual, but the needs of modern war have led and accelerated the process.²³ Modern war has required propaganda to sustain morale among the civilian population which, contributing directly to the war effort, can no longer expect to be exempt from attack. Modern war has also required an adjustment of the nation's economy to its needs. A free market system, depending on profits, has proved less adequate than military discipline for reducing private consumption and directing resources and productive energy to war requirements. Since transition from a free economy to a controlled economy would be difficult in the presence of war, preparation for war tends toward such a change in time of peace. Furthermore, autarchy is necessary as a defense against blockade. The controls necessary to confine the nation's economic life to those regions whose resources and markets will be available in time of war must be applied before the war. The modern technique of war has, therefore, led to the autarchic totalitarian state and the elimination both of free economy and free speech.²⁴

(e) A fifth change, characteristic of modern war technique, is the breakdown of the distinction between the armed forces and the civilians in military operations. The moral identification of the individual with the state has given the national will priority over humanitarian considerations. The civilian's morale and industry support the national will. Thus the population, manu-

²³ Walter Lippmann discussed, in 1937, various factors which had weakened liberalism since 1870, but concluded "There is only one purpose to which a whole society can be directed by a deliberate plan. That purpose is war, there is no other." ("The Good Society," p. 90.) In 1884 Herbert Spencer saw collectivism leading to "militant communities organized for a state of constant war" ("The Coming Slavery").

²⁴ Speier and Kähler, *op. cit.*

facturing and transport centers have become military targets.²⁵ Since bombing aircraft and starvation blockades have made it possible to reach these targets over the heads of the army and fortifications, the principle of military necessity has tended to be interpreted in a way to override the traditional rules of war for the protection of civilian life and property.²⁶

While distinctions according to extensive exemptions to the noncombatants, the civilian population and the national economy may still be supported by reference to the sources of international law, the practice of war has tended to become totalitarian. Starvation, bombardment, confiscation of property and terrorization are considered applicable against the entire enemy population and territory, except in so far as practical dangers of reprisal and a desire to utilize the population of occupied areas may inhibit. The entire life of the enemy state comes to be an object of attack.²⁷ The modern doctrine of conquest even extends to the elimination of that population and its property rights in order to open the space it occupied for settlement.²⁸

(f) A sixth characteristic of modern war technique has been a great increase in the intensity of military operations in time, and of their extension in space.

Operations of war have always had the object of concentrating a greater

²⁵ John Westlake, Chapters on "The Principles of International Law," Cambridge, 1894, p. 273.

²⁶ Q. Wright, *Minnesota Law Review*, 1921, vol. 5, pp. 520 ff. For general discussion of doctrine of military necessity see Westlake, *op. cit.*, pp. 238 ff.; U. S. Rules of Land Warfare, 1914, Arts. 10-13.

²⁷ Rudolf Littauer, *Enemy Property in War*, in Speier and Kähler, *op. cit.*, pp. 279 ff.

²⁸ Arthur Feller, in Speier and Kähler, *op. cit.*, p. 153. This radically changes the assumption on which arguments, such as that by Norman Angell ("The Great Illusion," 1911), against the utility of conquest were based.

military force than the enemy at a given point, the control of which is regarded as important. Such points might be fortified places, government or commercial centers, transport and communication gateways, or a battle-ground selected by the enemy or one to which his forces might be lured. The party with inferior forces would try to delay action while he brought up reserves and improved his trenches, but if one acquired marked superiority at any moment he would usually begin a battle or siege. This episode would end in retreat or surrender by one side after a day or, in the case of siege, after several months and would be followed by months or years of maneuver during which another point of importance would emerge, forces would be concentrated, and another battle or siege would occur. The campaigns would thus be broken into distinct and separate episodes but, because of the slowness of communication and the difficulties of winter fighting, campaigns in separated areas or in different years would be, in considerable measure, isolated from one another. War typically consisted of a number of distinct campaigns separated by long periods and wide areas of relative peace.

The inventions in mechanization and mobility, the organization of the entire population, the increase in the number of important targets for attack, has made it possible to concentrate enormously greater forces at a chosen point, to supply reserves, and to continue attack and resistance at that point for a much longer period, to increase the number of points being attacked simultaneously, to enlarge the theater of the campaign by mutual efforts at outflanking, and to coordinate operations on all fronts, at all seasons, for the entire course of the war. The result was that the World War of 1914 tended to become a single and continuous campaign, and the campaign tended to become one long battle or a

series of battles so overlapping and united as to be hardly distinguishable.²⁹ The pattern of war, instead of a grouping of dots on a map, became a large black spot of ink on the map which spread rapidly until the entire map was blackened. While this pattern was not at first duplicated in the hostilities which began in 1931, the new *blitzkrieg* and siege tactics may eventuate in an intense, continuous and universal battle. The continuous bombardment of London indicates such a development.

These six characteristics of modern military technique—increased mechanization and size of armed forces, more general militarization and nationalization of the people, greater extension and intensity of operations in regard to objectives, duration and theater—collectively tend toward totalitarian military organization of the belligerents and totalitarian military operations during the war. Though a trend in this direction began in the sixteenth century, it has been more and more emphasized during the past fifty years, with a marked acceleration during the past decade.

These changes have been most marked in the characteristics of weapons, less marked in that of organization and operations, and of little significance in the fields of policy and strategy. The art of using superior preparedness and a reputation for ruthlessness and threats of war for bloodless victory are as old as Machiavelli, though the vulnerability of civilians to bombing aircraft may have increased the effectiveness of these methods against nations which have greater potential power than the threatener.³⁰

Writers on modern strategy can still draw lessons from the campaigns of Hannibal, Caesar, Frederick and Napoleon.

²⁹ The war of position is well described by Lt. Col. Asan, *op. cit.*, pp. 5 ff.

³⁰ H. Simons, *Power Politics and Peace Plans*, and Max Ascoli, *Peace for Our Time*, in Speller and Kähler, *op. cit.*, pp. 19 ff., 348 ff.

The importance of a clear *objective*, of seizing *offensive* opportunities, of striving for *mobility* are still important. The principles of *surprise*, *concentration*, *co-operation* or team work, *economizing of forces* through flexibility and maneuver, *security* of bases and positions continue applicable, though the conditions of their application have greatly changed.³¹ The number of points on the earth's surface vulnerable to military surprise has been increased by the airplane, as has the quantity of force which may be concentrated at a point, and the possibility, afforded by electrical communication, of cooperation over a large area. The possibilities of maneuver, while increased in strategy, because of new means of mobility, has decreased in tactics, because of the larger forces engaged and the increased difficulties of outflanking. While all bases have become more vulnerable to surprise attack, the possibility of holding positions has not greatly changed. The arts of fortification, entrenchment and anti-aircraft defense have progressed with the progress of artillery and aviation.

Because of these changes some writers have asserted that there has been a change in basic strategic principles. It has been said, for instance, that the general objective of war is no longer to disarm the enemy by destroying or capturing fortifications and armed forces, but to evade them and to strike at the government or economic nerve centers of the enemy directly. Such a change in objectives, it has been thought, might modify the principles of concentration and security.³² It appears, however, that recent wars do not support this theory. The old principles continue to be observed under the new conditions.

³¹ Major General Sir F. Maurice, "Principles of Strategy," New York, 1930; Col. J. F. C. Fuller, "The Reformation of War," 1922, pp. 28 ff.; Rear Admiral Bradley A. Fiske, *op. cit.*, pp. 345 ff.

³² *Supra*, note 15.

The *blitzkrieg*, using airplane and tank, still aims at disarming of the enemy, though destruction of airdromes, communication and transportation centers, and lightening mechanized invasion, are, under modern conditions, the first step in this process.³³

3. POLITICAL EFFECTS OF MODERN MILITARY TECHNIQUE

Contemporary war appears to have made for instability, political disintegration, dictatorship and unadaptability. A final evaluation of the political effects of the most recent development of military technique must await the result of the second world war. The influence of these techniques upon the disposition of statesmen to threaten or to resort to war, and upon the political effect of such action can, however, be already observed and such observations seem to support our general analysis of the rôle of war in contemporary civilization. Four conclusions seem justified.

(a) Nations skilled in modern military techniques have an overwhelming advantage over those not so skilled.³⁴ This was manifested in the tremendous advantage of European nations which first began to adopt modern military techniques over the American and Asiatic states opened to them by the discoveries of the fifteenth and sixteenth centuries. The spread of

³³ Henry J. Reilly, *Foreign Affairs*, January, 1940.

³⁴ Adam Smith pointed out in 1776 that "In ancient times the opulent and civilized found it difficult to defend themselves against the poor and barbarous nations. In modern times, the poor and barbarous find it difficult to defend themselves against the opulent and civilized. The invention of fire-arms, an invention which at first sight appears to be so pernicious, is certainly favorable both to the permanency and to the extension of civilization." (*Op. cit.*, book 5, chap. 1, conclusion.) See also, Liddell Hart's conclusions on the Italo-Abyssinian war (1935) in which the Abyssinians had almost no defense against air and gas attack and his conclusions on the Spanish civil war (1937). "Europe in Arms," New York, 1937, pp. 251 ff.

European imperialism followed. With the development of these techniques in the United States, Japan and other overseas states, the European empires have been seriously shaken. The accelerating development of the modern techniques in the last ten years, however, has given rise to new differentials. Consequently, all states have felt obliged to move in the direction of totalitarianism and to equip themselves with the latest devices or to place themselves under the protection of states so organized and equipped.

(b) Modern military techniques, however, have increased the probability of a deadlock and a war of attrition between powers which are equally skilled in the use of these methods. Experience with an inflexible technique tends to favor the defensive, and highly mechanized techniques tend to become inflexible. The success of the offensive depends in large measure upon surprise,³⁵ and as the varied applications of a given technique become known, the opportunities for surprise become less. On the other hand, the defensive depends upon knowledge of the best means of dealing with the enemy's offensive and this knowledge steadily accumulates with experience of a given technique.³⁶ This is true of any form of conflict, whether with a serious objective or for sport. In the hands of experts, chess is far more likely to result in a draw than in the hands of amateurs, and football has shown the same tendency, with the result that the rules have been frequently changed to favor the offensive and keep the game interesting.³⁷

³⁵ "Rapidity of movement and surprise are thus the life and soul of the strategical offensive." (Vonder, Goltz, "The Conduct of War," London, 1908, p. 34). Fiske, *op. cit.*, p. 40.

³⁶ "The modern tendency to keep up the international *status quo* arises from the great age of all European states. This sentiment naturally fits in with the spirit of the strategical defensive, the principle of which is likewise that of keeping up the *status quo*." (Vonder, Goltz, *op. cit.*, p. 63).

³⁷ Q. Wright, "The Causes of War and the Conditions of Peace," pp. 49 ff.

While the rapid progress of military invention during the past fifty years has provided opportunity for new surprises, on the whole it has tended toward more mechanization and capitalization of military technique favoring the war of attrition."

Furthermore, the masses involved in a major modern battle have become so large that they cover the entire front. No maneuver can get around the flanks of an enemy whose line extends along the entire frontier.³⁸ The *blitzkrieg* coordinating plane, tank and infantry broke through at the weakest point when assisted by the element of surprise and great superiority of material.³⁹ The aerial bomber with its power of hitting the enemy's nerve center directly may break the deadlock. The airplane has undoubtedly made the civilians and the national economy vulnerable to attack. The fear of reprisals is the civilian's only defense from aircraft.⁴⁰ But to say that each side can destroy the other's civilians and cities does not say that rapid victory can be won by doing so if there is comparative equality of planes and productive capacity. Under such conditions war may continue in the course which Bloch predicted and the World War demonstrated, toward mutual attrition.⁴¹

³⁸ Col. J. F. O. Fuller, *op. cit.*, p. 88. See also J. Holland Rose, "The Indecisiveness of Modern War," London, 1927, p. 47; Liddell Hart, *Atlantic Monthly*, December, 1936.

³⁹ This was to some extent anticipated in England. Fuller, *op. cit.*, chap. 8; Nickerson, *op. cit.*

⁴⁰ British Prime Minister Baldwin said that against air attack "the only defense is offense, which means that you have to kill women and children more quickly than the enemy if you want to save yourselves" (quoted by B. Russell, "Which Way to Peace," p. 21, who quotes to similar effect Brigadier General Graves, "Behind the Smoke Screen," and Air Commander Charlton, "War from the Air," 1935).

⁴¹ Bloch, "The Future of War," pp. 347 ff.; J. Holland Rose, *op. cit.*; Fuller, *op. cit.*, chap. 4. The question is still controversial. See Nickerson, *op. cit.* Hostilities in Spain and China suggested that anti-aircraft defense had progressed more rapidly than air attack. The

(c) The skills involved in modern military techniques tend to be less the capacity to command armed forces in the field than the capacity to manage the national economy, to sustain the national morale, to destroy the enemy's morale and economy, and to handle neutrals diplomatically—in other words, the rôle of strictly military operations, in wars between states of equal technological development, has tended to decline. Wars were formerly won through military operations in the field and this is still true where a powerful state with the latest military techniques attacks one smaller, more backward, or less prepared. States may, however, fail to win wars over their technological equals, even though they win most of the battles. With the totalitarianization of war the cost of winning battles may make them Dead Sea fruit to the victor.⁴² With this development, economic strength, propaganda strength and diplomatic strength have increased in relative importance.⁴³ After both sides have been ruined, the

Albanian, Polish, Danish, Norwegian and, in a less degree, the Finnish campaigns of 1939-40 demonstrated the possibilities of the Blitzkrieg against an inferior enemy. (See Henry J. Reilly, *Foreign Affairs*, January, 1940, pp. 254 ff.; J. M. Spaight, *ibid.*, pp. 357 ff.) Similar methods proved successful against France. (Hoffman, Nickerson, *Harper's*, August, 1940, pp. 239-48.) For difficulties of this type of war against an enemy of vast area and population like China see Kurt Bloch, *Institute of Pacific Relations, Inquiry Series*, 1939, pp. 48 ff., quoting W. Schenke, *Zeitschrift für Geopolitik*, 1938, pp. 705 ff. See also R. E. Dupuy, *Pacific Affairs*, June, 1939, pp. 138 ff.

⁴² See James T. Shotwell, *op. cit.*, pp. 144 ff.

⁴³ In distinguishing the military, economic and propaganda fronts in war, H. D. Lasswell ("Propaganda Technique in the World War," London, 1927, pp. 9, 214) follows Clausewitz, who wrote: "There are principal objects in carrying on war, (a) to conquer and destroy the enemy's armed forces, (b) to get possession of the material elements of aggression, and of the other sources of existence of the hostile army, (c) to gain public opinion." (Major Steward L. Murray, "The Reality of War," London, 1914, p. 69.)

coalition controlling most population, raw materials, industrial equipment and civilian morale may win because the other has run out of one of these items and the control of sea-borne trade may continue a major factor in lasting capacity.⁴⁴ The significance of propaganda has been illustrated in the policies of Hitler and Mussolini.⁴⁵ Bismarck recognized the importance of the imponderables in war, and the superior diplomatic ability of the Allies in winning neutrals contributed greatly to their success in the World War. Rapid military victory may in fact prove a positive obstacle to diplomatic success. Neutrals, not too close to the scene of action, are likely to fear and distrust the government so well prepared that it wins initial military successes. For this reason, as well as from sympathy to the victim of invasion and a desire to restore the balance of power, such neutrals may give moral or even material support to the government which loses the first round.⁴⁶ Neutrals near to the initial victor tend, however, to jump on his bandwagon.

(d) The utility of military power has become distinct from the utility of military victory. As an instrument of policy, war is more useful because of its nuisance value than because of its capacity for positive achievement. It is like the bomb in the hands of a bank robber, which if tossed will destroy both bank

⁴⁴ Admiral A. T. Mahan, "The Influence of Sea Power on History," 1660-1783, 1899.

⁴⁵ H. D. Lasswell, *op. cit.*, p. 214. See also Admiral Hussey, "The United States and Great Britain," Chicago, 1932, p. 206. Military men have always realized "that in war we have to do not so much with numbers, arms and manoeuvres, as with human nature" (Henderson, "Lessons from the Past for the Present," quoted by Dupuy and Elliot, *op. cit.*, p. 41), but they have emphasized propaganda to increase the morale of our troops rather than to destroy that of the enemy.

⁴⁶ Q. Wright and Carl J. Nelson, *Public Opinion Quarterly*, 1939, vol. 3, pp. 49 ff.

and robber but which when threatened may induce the cashier to comply with demands peacefully. War is still in practice, if not in law, an instrument of national policy, but other instruments such as diplomacy, commercial pressure, propaganda or the invocation of international procedures are now available. These methods are used as auxiliaries to military attack, but they also constitute alternative methods which may be used for achieving policy.

The threat value of war as an instrument of policy may even have an inverse relation to its actual value as an instrument of policy. The excessively high costs of war have added to its nuisance value in the hands of adventurous statesmen. In proportion as war means ruin for all if actually resorted to, more responsible statesmen will tend to yield to the demands of those who threaten it. The bombing airplane, directly threatening civilian populations, has been particularly useful as a support for diplomacy and was doubtless largely accountable for the successes of Mussolini and Hitler in warding off intervention by England and France in the cases of Ethiopia, Spain, Czecho-Slovakia and Albania. In these cases war potential rather than war itself served as an effective instrument of national policy.⁴⁷ Since, however, the diplomatic use of war potential may easily result in war itself, destructive to the policies of all participants if not to civilization, there is a general interest in eliminating that use. Not only resort to war, but even more a threat of war should be regarded as a crime. It can not be said that Hitler's threat of war at Munich, in September, 1938, was any less criminal than his use of war in Poland in September, 1939.⁴⁸

Modern military technique has central-

⁴⁷ F. S. Dunn, "Peaceful Change," New York, 1937, pp. 8 ff.

⁴⁸ Q. Wright, *American Journal of International Law*, 1939, vol. 33, pp. 12-33.

ized world power in the governments utilizing it most efficiently, has made war suicidal among those powers, has diminished the rôle of strictly military activity in war, and has augmented the nuisance value of war threats to the unscrupulous.

4. THE FUTURE OF MILITARY TECHNIQUE

In the past, cycles of war have tended to move from (1) the technique of agility and pounce to (2) the technique of momentum and mass charge followed by (3) the technique of discipline and maneuver which in time moves to (4) deadlock and the war of attrition.

The first two of these four stages have in past civilizations been dominated by the offensive spirit illustrated in the classical civilization before the time of Augustus (27 B.C.) and in Western civilization before the "Babylonian captivity" of the Papacy (1309 A.D.). The last two stages have been dominated by the defensive spirit. Rome expanded little after Augustus but defended its frontiers. Christendom did little crusading after Boniface but defended itself from Arabs, Turks and Tartars.⁴⁹

A parallelism may, however, be detected between the offensive and defensive periods in that each began with reliance upon quality in its armies and ended with reliance upon quantity.

The military history of modern civilization exhibits analogies to these earlier civilizations. The highly trained but relatively small armies of the sixteenth, seventeenth and eighteenth centuries, capable of pouncing upon and paralyzing their enemies rapidly, especially when those enemies were Americans,

⁴⁹ The dates suggested for these dividing points are arbitrary. The end of medieval expansion might be pushed back to the fall of Acre in 1291, extinguishing the kingdom of Jerusalem or forward to the black death in 1348, which contributed much to the permanent elimination of the offensive spirit of medieval Christendom.

Asiatics or Africans without modern arms, grew gradually in size as populations increased and methods of transportation and communication improved. When at war with each other they relied more and more upon defensive fortifications and siegecraft, but their basic strategy and tactics continued with little change until the French revolutionary period.⁵⁰

Napoleonic doctrine, built on universal conscription and the revolutionary spirit, held that military power varies mechanically as the product of the mass and the mobility of the army. This doctrine, however, emphasized morale even more than materiel and might have been formulated from this point of view, that military strength varies morally as the product of the zeal of the nation, and the perseverance of the army in the strategic and tactical offensive.⁵¹ General acceptance of this doctrine of the nation in arms since the mid-nineteenth century may mark the transition to the second stage of modern warfare. National self-consciousness had been developed by Fichte, Mazzini and Treitschke,⁵² and the doctrine of mass warfare had been developed by Clausewitz and his successors especially in Germany.⁵³ The practice of this type of warfare was facilitated by the use of the railroad for mass mo-

bilization and of heavy mobile artillery for battering through. Its possibilities and tendencies were illustrated by the operations of Grant and Moltke, Kuropatkin and Oyama, Hindenburg and Foch.⁵⁴

Throughout the entire modern period the doctrine of the strategic offensive has in general dominated.⁵⁵ Modern civilization was expanding on land and sea, and by the time of the World War it had superficially covered the globe. There were still nooks and corners in Africa, the Pacific and Asia where it had not penetrated, but in the main its task appeared to be no longer external expansion but internal reorganization and integration.⁵⁶

The progress toward totalitarian war and the spirit of the offensive continues, but the war of 1940 differs from that of 1914 in its greater mechanization and greater reluctance to sacrifice masses of men in frontal attacks. While modern civilization, viewed in the large seems to be just passing from its "heroic age" to the "time of troubles," which in past civilizations has been characterized by an extraordinary development of mass warfare, this stage may be proceeding so rapidly that already signs are appearing of the third stage, that is, the war of maneuver with a defensive spirit and reliance upon the quality rather than the quantity of the army.⁵⁷

It is worth notice that while Classical

⁵⁰ See *supra*, notes 6, 7.

⁵¹ Nickerson, *op. cit.*, pp. 141 ff.; Liddell Hart, "The Remaking of Modern Armies," pp. 88 ff.

⁵² On the rise of modern nationalism see O. J. H. Hayes, "Essays on Nationalism," New York, 1926; J. C. King, *Some Elements of National Solidarity*, Manuscript, University of Chicago, 1933, chap. 9.

⁵³ See works of Vonder, Golts, Bernhardt, Freytag-Loringhaven cited. "The conduct of war . . . has generally been supposed to mean the direction of armies and navies and therefore a matter to be left to soldiers and sailors. To-day at least we should be aware that it means the direction for a special purpose of the whole power and resources of the nation." Major General Sir Frederick Maurice, "Governments and War," London, 1926, p. 123.

⁵⁴ See Rose, *op. cit.*, chaps. 1, 2; A. L. O. Moltke's Plans of Campaign, "The Military Historian and Economist," 1916, vol. 1, p. 297; Col. J. F. C. Fuller, *op. cit.*, pp. 75 ff.

⁵⁵ There was an exception in the eighteenth century with respect, however, only to European wars. Nickerson, *op. cit.*, pp. 114 ff.

⁵⁶ See Ramsay Muir, "The Expansion of Europe," Boston, 1923; P. T. Moon, "Imperialism and World Politics," and Schuman, *op. cit.*, pp. 93 ff. for description of the process by which Europe expanded over the world.

⁵⁷ Such a transition is anticipated by such military writers as Fuller, Liddell Hart, Nickerson, etc.

and Western civilizations each made such a transition in military techniques, the political consequences of the change were different in the two cases. Classical civilization having become politically organized in the universal state of Rome, the army became the police force of that state, efficiently defending its frontiers and preserving internal peace for over two centuries. In Western Christendom, on the other hand, Boniface's hope of a centralized control by a universal church, Dante's hope of a centralized control by a universal empire, and Dubois's hope of a centralized control in a universal federation of monarchs—all three expressed in the first decade of the fourteenth century—failed of realization.⁵⁸ The Holy Roman Empire and the Catholic Church were weakened by internal dissension. Mercenary armies served to defend Christendom, efficiently in Spain and inadequately in the Balkans, but they did not constitute the policy of a centralized Christendom. They were armies of the rising national states, not all of which were satisfied to defend existing frontiers. England had been expanding at the expense of Wales, Scotland and Ireland and was about to wage the Hundred Years' War of conquest against France, and then to endure the bitter Civil War of the Roses; Switzerland and Bohemia were to struggle for independence; Italian states were to engage in a series of struggles for ascendancy in the Italian peninsula, as were Spanish states in the Iberian peninsula and German states in the empire. The *Pax Ecclesia* did not achieve so enduring an organization as did the *Pax Romana*. Western civilization declined in ceaseless internal wars of contending states and factions and steadily lost territory to the Turks, until it began to be absorbed by the rising world civilization, inaugurated by

⁵⁸ These proposals are summarized by Frank M. Russell, "Theories of International Relations," New York, 1936, pp. 99 ff.

the discoveries, the inventions, the Renaissance and the Reformation.⁵⁹

Proposals which have been made for a more scientific organization of peace and for a more scientific organization of war suggest the alternatives before the contemporary world. The offensive power of armies may be so much weakened through continuance of the nineteenth century trend, perhaps augmented by disarmament agreements and change of popular evaluations from the standards of national power to those of human welfare, that all will give up the hope of or interest in conquest, and an adequate world organization with an efficient police may be able to assure both collective security and peaceful change. Such a trend may be illustrated by the federal organization of the United States, Canada, Australia and other states, by the change of the Monroe Doctrine from a policy of the United States hegemony to the Good Neighbor and Pan-Americanism, by the change of the British Empire to a voluntary commonwealth of nations, and by the attempts at world union at the Hague and Geneva.⁶⁰

On the other hand, national states may modify the techniques of their armies so as to favor the offensive, as suggested by recent experience with the *blitzkrieg*, and a period of balance-of-power wars may prevent the integration of such a collective system and tend toward a series of regional hegemonies. These might eventually reach a stable equilibrium, or one might conquer the rest and establish a world empire.

It can not be denied that the trend of military history since 1932 has looked toward a third alternative. On the one

⁵⁹ See Oman, "The Art of War in the Middle Ages"; "The Sixteenth Century," London, 1936.

⁶⁰ See Lord Davies, "The Problem of the Twentieth Century"; Russell, *op. cit.*, pp. 327 ff.; Clarence Streit, "Union Now," New York, 1939.

hand, states have adopted more extensive conscription laws, have maintained larger standing armies, have voted larger military appropriations, have provided more complicated frontier defenses and have striven for a higher degree of economic self-sufficiency, thus preparing for total war. On the other hand, they have utilized centralized propaganda instruments and economic controls to develop in each population a more fanatical and aggressive national spirit. The combination of these policies, which has precipitated the second world war, may tend toward frequent general wars on a gigantic scale and the eventual destruction of civilization.

This article has discussed the application of invention to war. But inventions are also applicable to peace. The

railroad, steamship, motor car and airplane have shrunk travel and transport distances so that the world is no bigger to-day than was Europe in the time of Napoleon. The cable and radio have shrunk the communication distances so that the world to-day is no bigger than was a village a century ago. These inventions have brought all sections of the world into relations of economic, political and cultural interdependence. They have destroyed the security of geographic barriers and made every people vulnerable to propaganda, embargo and military attack. They have created both the possibility and the necessity for organizing the world as a whole for peace. What use will be made of inventions belongs, however, not to technology but to the human spirit.

SCIENCE SERVES ALL NATIONS

Too often increased knowledge of natural forces, acquired by scientific studies, has been employed in harmful as well as in beneficial ways. To these balanced consequences, good and evil, the consequences of medical investigations, as previously noted, are in striking contrast. It would be difficult, if not impossible, to find that any one of the many important discoveries made in the medical sciences during the past hundred years has been used by fighting forces for the destruction of life. . . .

There is another consideration eminently creditable to the efforts of medical investigators. Because life and health are precious and medical research is deeply concerned with protecting life and health, the triumphs of that research are put to use without regard to any national or racial difference. There is no escape from the succor which they bring. Even though the beneficiaries may despise their benefactors, they must receive the benefactions. Is a follower of the Fuehrer bleeding to death and desperately dependent on a blood transfusion? His life is saved by methods discovered by Landsteiner, once an Austrian. Does a Japanese complain of a bewildering dizziness caused by disturbance of the internal ear? He will be in debt to Bárány, a Hungarian investigator. Does an Italian doctor wish to

know whether a patient has typhoid fever? He applies observations first made by Widal, a Frenchman. Is one of our children in danger of diphtheria? His resistance to infection is tested by a process invented by Schick. Goldberger, an immigrant to New York's East Side, provided a simple preventive and treatment of pellagra, which made possible lifting, from hosts of miserable people, the blight of that dreadful disease. And no matter in what country they may be, the tens of thousands of victims of syphilis must rest their hope of relief on a method of diagnosis first devised by Wassermann, and on a curative method discovered by Ehrlich, both Germans at a time when Germany recognized, without contempt and malignity, the value of ingenious devotion to human welfare. All these contributors to medical knowledge have been citizens of various lands, but they would all be classed as belonging to one people. And though in the last years their people have been again savagely and sadistically persecuted, no nations, however hostile, can take from these medical representatives the honor and glory of having served as saviors of their fellow men.—*Walter Bradford Cannon, in the symposium, "The University and the Future of America," at Stanford University.*

SARGASSO SEA MERRY-GO-ROUND

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I

STORY-TELLERS have created the illusion that the Sargasso Sea is a forbidding region of the tropical Atlantic, where wrecked and abandoned ships of all ages lie cluttered in one enormous, slowly rotating mass.

The Sargasso has become known as a sort of marine purgatory. According to romanticists hulks of broken, barnacle-covered galleons float, half-sinking, in the very center. Surrounding this decaying and weed-entangled core, skeletal keels of wretched African slave ships and the pirate ships of the Caribbean buccaneers make their monotonous rounds. Encircling these bloody ships come the unfortunate ships of the Revolutionary period, the once slow majestic windjammers, the once fast clipper-ships, the once sturdy whalers, now all weed-grown, slimy and disintegrating. Finally, on the outermost fringe of this sea-hell, circle the last remains of recent naval catastrophes. As long as these doomed vessels stay afloat they keep up a barely perceptible, yet never-ending parade in their circular marine limbo.

Geographers, too, have called the Sargasso a *sea*. But, in reality, it is not a sea, at least not a good example of a sea, like the Mediterranean, for instance. All good seas, geographically speaking, have land boundaries that set them off, for the most part, from the open ocean. No land boundaries confine the Sargasso Sea, for it lies within the heart of the Atlantic Ocean itself, a sea within a sea, like a hub within a wheel. As powerful oceanic currents and winds turn the watery wheel of the Atlantic round and round, the Sargasso hub turns within the wheel.

Seaweeds, not land boundaries, set off

the Sargasso as a distinct area of the Atlantic. No other region on this planet, either on land or water, produces so great an acreage of a single species of plant. All the wheat fields of America put together are like back-yard gardens compared with the vastness of the Sargasso Sea, the home of Sargassum weeds. The extent of Sargassum's habitat is not measured in terms of acres, but by degrees of latitude and longitude. Picture a triangular marine garden bounded on the southwest by the Antilles, on the northeast by the Azores, and on the southeast by the Cape Verde Islands. These landmarks on the oceanic expanse denote a region of the sea, roughly, between the thirtieth and fortieth parallel of north latitude and between the thirtieth and seventy-fifth meridian, longitude—an area approximately the size of continental United States, some 2,500,000 square miles.

The barriers which confine the Sargassum weeds to their extensive, but nevertheless restricted, bounds are chiefly the great oceanic currents. The powerful Gulf Stream comes up from the south and flows along the western fringe of the Sargasso. It sweeps north and then east towards Europe. The Canary Current continues the relay race of the oceanic circuit by running south where it meets the North Equatorial Current, which, in turn, takes its charge to the province of the Gulf Stream and completes the circumfluence of the Sargasso.

Since the sea-fences around the Sargassum weeds are liquid forces, not solid barriers, it is to be expected that oceanic disturbances occasionally shift or break the circular marine zone that confines the plants. Rafts of floating Sargassum,

in freight-boat loads, have been swept northwest to Massachusetts and northeast to the coast of Europe. Almost ninety years ago, William Harvey, keeper of the herbarium of the University of Dublin, said that the Sargassum weeds have "no just claim on our flora, being native of the tropics, occasionally driven together with cocoa-nuts and other tropical productions by the force of the western currents on our Atlantic coasts." For years the hardy Scotch and Irish cattle herders have depended upon the adventitious harvest of this and other seaweeds as winter storms fringe their rocky coasts with free gifts of these valuable sea-vegetables. Perhaps those salt-encrusted husbandmen and their families do not mind the strong fishy flavor that seaweeds impart to the milk. At any rate, they are well compensated, for it is certain that few of them ever suffer from goiter; it is well known that these fucaceous algae, while pungent in flavor, are rich in beneficial salts, particularly iodine and potassium. With the return of normal climatic conditions in the Sargasso, the weeds are herded together again; they return to their circular parade within the confines of their sea-stream corral.

In spite of the liquidity of its barriers, the Sargasso Sea has characteristics, apart from its famous weeds, which set it off from the rest of the ocean. Its waters are relatively motionless, warm, deep blue in color, highly transparent and highly saline. Being at the hub of the ocean whirl, the Sargasso turns more slowly than any other part, although it seemingly turns hardly at all. Its waters are warm because they are located near the equator, and, in addition, they are surrounded by warm oceanic currents. The waters are deep blue, highly transparent and highly saline, all for the same reason, because the Sargasso is far from continental influences. By the time continental rivers that bring to the sea the run-off waters of

melting snows and the wash of the land reach the vicinity of the Sargasso in mid-ocean, the river water is no longer fresh nor loaded with silt. The clarity of the water of the Sargasso is remarkable. United States oceanic expert, H. A. Marmer, says he could see a six-foot white disc at a distance of 200 feet below the surface. And that is nearly a perfect reading.

The deep-blue color is due to great depth of water, the lack of turbidity and the scarcity of microscopic marine life. The floating, pelagic, planktonic organisms are nowhere scarcer in the ocean than in the Sargasso. Except for the floating world of Sargassum weeds and their animal associates and dependents, the Sargasso is virtually a desert.

The power of the Gulf Stream to turn, not only the Sargasso hub, a mere 2,500,000 square miles, but the entire oceanic wheel is remarkable indeed. Here is how Marmer illustrates its stupendous power. The Mississippi River drains 40 per cent. of the United States; at flood time, when it has three times the normal flow, the Mississippi pours 1,800,000 cubic feet of water per second into the Gulf of Mexico. It would take close to 500 Mississippi Rivers, all flowing at once, at flood-stage force, to match the volume and power of the Gulf Stream.

II

The scientific game of cataloguing the species of Sargassum weeds has given botanists many headaches. William Randolph Taylor, the University of Michigan's expert algologist, who used to spend his summer vacations around the little inhabited coral reefs of Florida in his search for seaweed specimens, says that the dominant plant representative of offshore waters is *Sargassum natan* Meyen.

Sargassum represents, not one, but several kinds of weeds, all of which belong to the most primitive society of plants in the world, the Algae. Some

Sargassum weeds are attached to rocky shores by holdfasts; the free ends, supported by air bladders, rise and fall with the action of the tides. Their stems and branches are so tough and leathery that they can withstand the terrible beatings they constantly receive from the pounding waves. The famous wandering Sargassum weed, *natan*, of the open Sargasso Sea has no holdfasts. It lost its attachment organs long ago in geological time, but its stalks and branches have developed elaborately. To the layman, these parts of the lowly alga resemble, with amazing nicety, the stems and leaves of higher plants.

Many rock-bound Sargassum weeds are frequently torn from their island and continental attachments by extremely violent wave action. Living as fragmentary plants, they are carried out to sea by the Gulf Stream and often take up a wandering existence in the Sargasso. Many able botanists believe that the floating world of weeds in the Sargasso is made up entirely of such detached fragments, the supply of which is annually being replenished from the rich coastal seaweed crop. Sir John Murray, England's great oceanographer of the last generation, believed that this was the true source of supply. So did his compatriot, J. Arthur Thomson, who, in his "Biology for Everyman," said that the immense floating population of brown seaweeds constitutes a cemetery of dead and dying plants rather than a meadow of living plants. But the new school of oceanographers thinks that the bulk of the Sargassum weeds in the Sargasso is represented by a species indigenous to that region, one that has been born and lives its entire life in mid-ocean.

While it is true that the rock-grown species of Sargassum are frequently torn from their anchorage and, by virtue of their buoyancy, carried to the Sargasso, these straggling fragmentary plants are strangers to the gypsy life of

the native wandering Sargassum weed. The rock-reared weed-immigrants may seem to enter into the spirit of Sargasso Sea life by joining the circular parade, but the landlubber plants can not tolerate the never-ending mid-ocean merry-go-round for long; eventually they die.

The native pelagic seaweed of the Sargasso is equally ill at ease when forced out of its circular course on the high seas by storms and carried to hard uncongenial shores. It is totally unsuited to a sedentary life; it has no holdfasts with which to cling to the rocks, and it can not develop them. It is unable to live the life of an exile on any land. It is as helpless as a ship run aground; like a helpless ship, it is pounded to pieces and its parts are cast upon the shore.

The wandering and the sessile Sargassums are different in other habits of life, for the wanderer is a sterile species producing neither sperms nor ova; the sedentary weeds are fertile and reproduce in the approved biological manner. Professor A. E. Parr, Yale's Sargasso expert, says that the pelagic Sargassum has so unique a method of self-preservation that the word for it has not yet been invented. This plant does not reproduce itself by runners, tubers, buds or spores. In fact, it has no true reproduction at all; it simply grows at the tips and dies down at the base.

Over a hundred years ago, in 1830, Meyen, the botanist, said that the pelagic Sargassum was a sterile species, that it grew only at the tips. He claimed then that it was an independent plant and not one brought in by the Gulf Stream. Thus, in the fashion of the circular movement of the Sargassum weeds themselves, biologists have returned to an idea held many years ago.

From earliest times to the present, students of oceanic life have guessed at the quantity of weeds in the Sargasso. Oceanographer Parr has taken on the job of finding a better answer. On his expeditions to the Sargasso, and he has

directed three of them, he takes along a unique gadget, a specially designed Sargasso weed sampler. This device, when towed behind the ship, cuts exactly two-foot strips of the surface weeds. From the mountainous mass of figures that he has collected from the hauls made by the sampler in 3,000 miles of the Sargasso, Parr is willing to say that there are about 10,000,000 tons of seaweed in the Sargasso Sea.

Ten million tons of weeds would make an impressive pile, but when it is realized that the weeds are spread over a field of 2,500,000 square miles, the figure is less impressive. When the figure is reduced to terms of pounds per acre, the values are quite disappointing. It turns out that the Sargasso produces one and one-half pounds of seaweeds per acre. That is why the Sargasso is regarded as an oceanic desert by biologists; for, not only does the water of the Sargasso support relatively little microscopic life, but its main crop, seaweeds, is low in terms of yield.

III

In the popular mind, even to-day, the concept of the Sargasso Sea as a weird and horrid place is strong and widely prevalent. The growth of this romantic notion of the Sargasso is, in itself, a long and an exciting story.

On Sunday, the 16th of September, 1492, after eight continuous days at sea, Christopher Columbus discovered the floating world of the Sargasso. When 800 miles west of the Canary Islands, Columbus remarked that around their ship they found "much green floatage of weeds" which, to them, seemed like an endless prairie. The weather was pleasant and "the mornings were most delightful wanting nothing but the melody of nightingales."

The caravels ploughed through the marine prairie with ease for two days; then the ships met with "alternate changes of wind and calms." Columbus

continued to see large quantities of weeds, "such abundance of weeds that the ocean seemed to be covered with them," and after three days of idleness in the Sargasso, the Admiral was forced to write: "My crew has grown much alarmed, dreading they never should meet in these seas with a fair wind to return to Spain."

Some among Columbus's men first thought that the seaweeds indicated submerged rocks and feared going aground, but they must have been reassured on this point, for their longest plummet-line was unable to reach bottom. Yet the sight of the ever-present weeds, without the accompanying sight of land from which the rock-weeds, as they knew them, were supposed to grow, seemed uncanny. It was this disturbing scene, thinks John Fiske, in his straightforward history of the "Discovery of America," that revived the mariners' ancient fancies that they had arrived at that mysterious and impassable region of the Atlantic where ships are held fast in long entangling sea plants.

These legends of weed-cluttered impassable seas are ages old; they were 1,800 years old in Columbus's time. They go back to the times of Aristotle and his ancient geographies. One weed-strewn region was supposedly situated south of the Canary Islands and west of the Rio d'Oro off northern Africa. According to ancient beliefs, this region was situated somewhere on the edge of the western ocean, on the edge of the world as known in those days. The legends told of overbold sailors that dared to approach too close to these weedy areas. Some escaped with difficulty, others, entwined beyond their power to retreat, remained enmeshed and perished.

Of course there were skeptics. Columbus was one of them. Those who scoffed at these legends declared that the tales were kept alive simply to frighten masters of trading vessels from competing

for the lucrative Atlantic coastal shipping business. Cyrus Adams thinks that the Phoenician sailors' story of the "sea grass in the Atlantic, with pointed tops as sharp as needles and stalks as close together as wheat in the sheath, so that vessels could not stir if caught in it" was one of the best of early publicity stunts.

Yet one can easily appreciate the disquietude of Columbus's men. It was now eleven days since they had seen the green land vegetation and heard the shrill song of the wild Canary birds. Their ships were small and frail; two vessels had uncovered decks, open to the full force of the burning sun.

One man in recent times fully appreciated Columbus's predicament. He is G. F. Simmons, who led the Cleveland Museum of Natural History expedition into the Sargasso Sea on a specimen-collecting voyage on an old windjammer in 1927. This modern Sinbad of science says he could easily understand why the Sargasso Sea is shot with wild tales, for he and his companions were held in the weeds of the Sargasso under a blazing sun for more than a week, held, not by the weeds themselves, but by the lack of wind or current to take them away.

Columbus was destined to sail almost twenty days more before he, himself, detected, at two o'clock in the morning, a glimmer of light from a "small island, one of the Lucayos, called in the Indian language *Guanahani*." It was Friday, October 12, 1492. Columbus had discovered America.

IV

From Columbus's time to the present, strange conflicting stories of the Sargasso Sea have been told. Fernando Colon, in the history of his father's life, drew a dramatic picture of the great discoverer's difficulties in the Sargasso. Oviedo, in his "Historia," and Petros Martyr, in his version of the voyages, intimated that the masses of seaweeds

encountered by Columbus were so dense that they impeded the progress of the ships. Later-day observers added a little to our true knowledge of the Sargasso, but the commentators on scientific topics added much to the store of fables concerning it.

James Barbot was master of a ship that passed near to the Sargasso in 1700. In his log book this pertinent item appears for a day in June, the seaweeds were seen "for a space of forty or fifty leagues and so close and thick together in some places that a ship requires a very fresh gale of wind to make her way through; and therefore, we are very cautious to avoid them in our course."

To America's first outstanding oceanographer, Matthew Fontaine Maury, the Sargasso appeared, at a little distance, so thickly covered with gulfweeds that it seemed substantial enough to walk upon. Maury gained international fame as one who first charted the winds and ocean currents of North America. He is regarded by many as the father of the United States Naval Academy, yet, during the Civil War, he served the Southern States. He accurately visualized the cause for the almost perpetual calm of the Sargasso, and he is credited for a simple explanation of its movement and the reason for its location.

Take a basin of water, he said, and put into it some slips of wood, soapsuds and other flotsam. Then impart a circular motion to the water with a sweep of the hand and watch the result. The floating matter will almost directly gather into the very center of the basin, where the movement is the slightest, while the outer edge of the wheel, where the water is racing the fastest, will be left completely clear.

In 1867 Cuthbert Collingwood traversed the Sargasso and reported in the *Intelligent Observer* (A Review of Natural History, Microscopic Research and Recreative Science) that the Sargasso Sea, dependent as it is upon oceanic phe-

nomena, changes its position, extent and volume, according to seasons, storms and winds; but its mean position remains the same as it has always been since it was first discovered by Columbus.

In spite of these statements by trained observers, the true facts of the Sargasso were generally withheld. Even the textbooks of the late 1860's, such as Professor D. F. Amsted's "Physical Geography," continued to say that the brown weeds of the Sargasso Sea were so thickly matted that they hid the water, and that trees and other land plants were carried out to the sea within the sea.

From the deck of one of the first ships chartered primarily for a thorough scientific study of oceanic life, *H. M. S. Challenger*, Sir Wyville Thomson, the biological observer, saw no dense masses of weed in the Sargasso, merely single layers of feathery strands, floating free of each other. In his long report, "The Atlantic," that appeared in 1878, he said, too, that the *Challenger's* depth-determining devices indicated between 2,000 and 3,000 fathoms over the extent of the Sargasso Sea. No wonder Columbus's plummet-lines could find no bottom.

Those tremendous depths of over two miles in the Sargasso Sea were rediscovered by the oceanographers aboard the exploring ships of the Prince of Monaco. His Royal Highness, with ample funds from his famous casino, could well afford to indulge in his favorite hobby, the study of the natural history of oceanic life. He sent scientists, the world's greatest, France's Professor E. L. Bouvier among them, scurrying far afield to collect specimens and interesting facts for his private Monaco Oceanographic Museum in his own principality. The professors were just as eager as the Prince to gather a scientific harvest from the sea, and they made a good job of it. They searched the ocean's surface and its depths; they collected plants and animals; they neatly preserved, labeled and catalogued them.

They plumbed the ocean floor with leaded lines, and they discovered no graveyard of ships in the Sargasso but fine oozy mud at depths down to 11,364 feet.

The scientific reports of Sir Thomson and the Prince of Monaco did not appeal to news commentators, apparently, for the *Chambers Journal* of "Popular Literature, Science and Art" issued the following account of the Sargasso in May, 1897.

It is only natural that ships should carefully avoid this marine rubbish-heap where the Atlantic shoots its refuse. It seems doubtful whether a sailing vessel would be able to cut her way into the thick network of weeds even with a strong wind behind her.

With regard to a steamer, no prudent skipper is ever likely to make the attempt, for it certainly will not be long before the tangling weeds would altogether choke up his screw and render it useless.

The most energetic explorer of land or sea will find himself baffled with regard to the Sargasso Sea by the fact that it is neither one nor the other.

In their journal the imaginative William and Robert Chambers said that the Sargasso held "keels or skeletons of ruined ships, so covered with barnacles, shells and weeds that the original outline is entirely lost to view; and here and there a derelict ship, transformed from a floating terror of the deep into a mystery out of reach of men in a museum of unexplained enigmas."

With Chambers's easily available and seemingly reputable essay before them, the story-tellers got busy. Finding that Jules Verne's versatile mind had not yet invaded the Sargasso Sea, other pseudo-scientific writers took possession, unleashed their own inventive powers and created a fantastic floating world of their own.

Thomas Janvier, America's Jules Verne, utilized this gruesome locale in 1898 for his hair-raising novel, "Sargasso Sea." His young hero, Roger Stetworth, hearing of a job in the Indies, innocently takes passage on a ship which turns out to be a slave-runner.

He is robbed and beaten by ship's cut-throats and then thrown overboard. Roger manages to cling to a floating mast on the outermost fringe of the Sargasso. He drifts to the heart of the Sargasso Sea. Let him tell you what he saw:

Far away, under the red mist, across the red gleaming weed and against a sunset sky bloody red, I seemed to see a vast ruinous congregation of wrecks so far extending that it was as though all the wrecked ships in the world were lying huddled together there in a miserably desolate company.

Roger explores his fantastic world, finding dead men at their gun-posts on abandoned war vessels, seeing skeletons of slaves with their arm and leg bones encircled by iron shackles, and eye-witnessing two ghost-like men murder each other.

Roger eventually finds a small steam launch which he fixes for his escape from the Sargasso Sea. To students of oceanic phenomena, this incredible trip is the most startling part of the remarkable story. The tangle of weed, he says, is so heavy and solidly grown together that he is obliged to open a channel for his boat. First starting his engine, he rushes forward, and, taking a stand far over the bow, he begins the laborious task of cutting the thick vegetation with a hand saw.

"I had to stand like a machine there" he wrote—"endlessly hauling the saw up and endlessly thrusting it down. Behind me, my little engine plugged and snorted; over the bows below me, was the soft crunching sound of the weeds opening as the boat thrust her nose into it, and on each side of me was the soft hissing, rustling of the weeds against the boat's sides."

After a month of disheartening toil, traveling at the rate of three miles a day, Roger finally reaches open water, a passing ship and safety.

The same year, as if to refute the picture of horror that Janvier had drawn, Frank T. Bullen, first mate on an Ameri-

can whaler, described his pleasant experiences in the Sargasso in his famous book, the "Cruise of the 'Cachalot.'"

When eight days out of New Bedford, Massachusetts, Bullen says, they were within range of the Sargasso Sea. "It fell a dead calm, and the harpooners amused themselves by dredging up great masses of the weed, and turning out the many strange creatures abiding therein. What a wonderful life the weed is, to be sure!" Not only Bullen but others who were intent upon learning the truth of the Sargasso Sea were amazed at the strangeness of the animal life of the region.¹ Parkinson in "Amid the Islets of Sargasso Sea" described for readers of *Living Age* the beautiful phosphorescence of the weeds at night, eery lights that were created by millions of tiny sea organisms clinging to the floating weeds. Similarly, Charles F. Holder, foremost teller of tales of big game fishes, described the Sargasso as a veritable garden "traversed by a maze of mimic rivers as rich and deep in cobalt as the Florida sky above it." Far from being a region of desolation and horror, the Sargasso Sea was a place of vibrant life and serenity.

The campaign of debunking the horrors of the Sargasso continued. Thaddeus Dayton explained the "Mystery of the Sargasso Sea" for readers of *Harper's Weekly* of July 16, 1910. He described how the Norwegian bark *Crown*, wrecked and abandoned, drifted into the Sargasso Sea on one side and came out from the other, apparently passing right through the very center of the so-called city of dead ships. His story was followed by John Stevenson's. This narrative, in *Science*, records two passages through the heart of the Sargasso in 1910. Stevenson failed to see any sign of the reputed pestilential weed city; indeed, for distances of 1,500 feet he saw no weeds at all. And again in 1911 the

¹ For a picture of the strange animals of the Sargasso, see "Animals of the Sargasso Merry-go-round" by Myron Gordon in *Natural History Magazine*, 42: 12-20, 1928.

diligent *Review of Reviews* pointed out to a skeptical public that the records in *Pilot Charts*, covering a period of 23 years and describing the courses followed by 157 derelicts, indicated that the tales of jungle-like weeds in the Sargasso capable of stopping a ship were quite fantastic. These revelations were further confirmed by the reports that came from the *S. S. Michael Sars*, a ship commissioned to study the Sargasso Sea under the expert guidance of Sir John Murray.

The sedate oceanographic records on the Sargasso, as before, failed to reach a large part of the reading public. The cut-and-dried statistics of little-known scientists did not stand out against the dramatics of novel heroes and their exciting adventures. Scientific reports did not stop Justus Miles Forman from writing, *Collier's* from publishing and *Collier's* readers from thoroughly enjoying, in 1911, that tingling story called "Sargasso Sea" in which most of the action takes place in that "dismal sea," "that heaving swamp," "that tract of mystery and death."

The much-maligned Sargasso flashed into prominence again in the early 1920's when Captain A. E. Dingle spun a yarn around Sargasso Sam, a lad found shipwrecked in the "golden, weed-choked, azure sea that fable and superstition have peopled with dead men and filled to congestion with the wrecks and ghosts of dead ships." Readers of the *Saturday Evening Post* for May 5, 1923, will recall with delight Sargasso Sam's physical and mental resurrection.

When William Beebe announced his projected Sargasso Sea expedition, the *New York Times Magazine* of February 15, 1925, headlined it: "THE ARCTURUS WILL EXPLORE SARGASSO SEA IN SEARCH OF LITTLE KNOWN MONSTERS. OFF TO THE FABLED SARGASSO!" This inspired an outburst of editorial and factual comments. *Popular Mechanics* described the ingenious technical gadgets on the *Ar-*

turus. *Radio Broadcast* described radio's part in preparing to announce the day-by-day discoveries. Editorials appeared in the *Nation*. *The Independent* deplored Beebe's expedition, exclaiming wistfully that it would destroy the people's faith in the romantic legends of the Sargasso. It wrote: "How many dull eyes have brightened over the imaginary contemplation of that fleet of stately Spanish galleons drifting forever in the silence, of the skeletal captain in his cabin sitting at his dice and wines, the crew all tattered skeletons, the cargoes of diamonds, emeralds and gold moldores." But when Beebe took his laboratory ship to where the Sargasso Sea was supposed to be, he found no mass of weeds larger than a man's head. That was ironic. While Beebe's radio story of his poor luck was rushing through the air on its way to the *New York Times*, it was picked up by Captain Harry Sumner aboard the freighter, the *Clan MacFayden*, a thousand miles away, but still within the Sargasso. While the *Arcturus* was anxiously searching the sea for weeds, the *Clan MacFayden* was wallowing in "weeds so dense that with full steam ahead the large freighter seemed to be held back."

The explanation for this seemingly contradictory evidence is that a rare and violent storm had hit the Sargasso during the early spring of 1925 and apparently had scattered patches of Sargassum in some regions and piled them together in others.

So again in modern times, in the present period of the twentieth century, some sailors confirm and others deny Oviedo's sixteenth century story that the *Sargaço*, a sea of little grapes, is a *praderias de yerva*, a weedy prairie, so thick that it is capable of slowing the progress of a vessel. And it is probable that as long as men sail the seas and men write stories, the cycle of tales concerning the Sargasso will go round and round like the course of the weedy sea itself.

AN INTERESTING BOOK

By W. L. McATEE

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THE copy before me has the appearance appropriate to an interesting book of a certain degree of antiquity. Some of its pages are loose and worn; its back is broken; it has been scarred by service. It has passed through many hands and has been annotated by some of them. The notes but add to the interest of the volume.

The book is entitled, "The Market Assistant" and it was published at New York City in 1867 (455 pp.). Devoted to "what we eat," it is not, however, restricted in scope, but records anything and everything of interest connected with food. The quaint, the ordinary, the veritable and the speculative, all find place in its pages; it informs, surprises, pleases. Would you learn about market grafting and lying, or the origin of porterhouse steaks, the dangers of grand dinners or the introduction of potatoes to England, the carving of human dentures from cattle teeth, or the beginnings of fish culture, the author is your guide. He makes a point of naming individuals connected with "curious incidents and anecdotes," thus furnishing a happy hunting ground for the genealogically inclined. Sample entries are:

Adams, John Q., presented with a large Cod-fish,

Astor, John Jacob, presents the skin of a "white wild sheep,"

Beebe, Theophilus, assists to take a monster Vampyre of the ocean,

Braisted, G., takes a Spotted Gunnel out of an oyster,

Cadwallader, General, of Philadelphia, dines on a large Brook Trout,

Cooper, Peter, purchases cattle feet for making glue,

Dwight, Dr. Timothy, on the Horse Mackerel,
Greeley, Horace, on the flesh of the Prong Horn.

Others there are by the score. The conclusion may be that the author could have been the gossip columnist of his day. If that implication is an unpleasant one, the reviewer feels that it is unjustified, for our author deals only with subjects that are legitimate objects of human curiosity.

A previous work, "The Market-Book," by following the same custom of recording names, drew the fire of "An Indignant Gentleman" who objected to his ancestors being recorded as butchers. "If my grandfather chose the trade of butcher, why should I be blamed for it? . . . All that I can do is to denounce the author . . . as a reckless disturber of family pride. In behalf of many proud and wealthy families of New York, I [so] denounce him." The author, Thomas Farrington De Voe, did not share the views of this correspondent, for at the end of the preface he signs himself "Butcher." Evidently there are butchers and butchers and De Voe, by his works, stands forth also as a scholar, a historian and an artist. The well-executed frontispiece of "The Market Assistant" vouches for the third of these specifications, both of his books for the second, and his thorough gathering of their materials for the first. As a particular point of scholarliness, book users will appreciate the 20-page classified index. It was made to help them and it serves. The section called "general index" leads to all the "curious incidents and anecdotes" and shows that the author knew them to be a feature of his work that would be appreciated. Within proper limits of a review, their diversity can be no more than indicated. They deal much with large things or accoun-

plishments. There is, for instance, record of an oyster measuring $37 \times 23\frac{1}{4}$ inches, of a sturgeon weighing 354 pounds and of a leather turtle of 800 pounds. The "largest woodcock found on record" (1 pound, 1 ounce) shot in Washington Township, New Jersey, in 1859, could only have been a specimen of the European woodcock, a species that has been collected only a few times in North America.

Among the anecdotes are such certainly unusual items as the catching of three fishes on one hook and the killing of three otters at a single shot. There is an account of a side hunt for woodchucks in Massachusetts in 1820 in which 1,154 of the animals were destroyed by one party and 873 by the other. The vegetable kingdom is not ignored, witness records of the production of 1,528 pounds of pumpkins from two seeds, and a season's yield of 108 gallons of sap, making 33 pounds of sugar, by a single maple tree.

Among curious notes are those relating to a two-headed terrapin and to a sea-serpent of the early 1800's which, upon capture, proved to be a horse-mackerel or tunny. De Voe records an alligator that was killed near Bushwick Ferry, Long Island, in 1815. As at that early date, transport of the animal from the South was unlikely, this occurrence may be proof of extended natural wandering by this animal which appears to be almost as much at home in salt, as in fresh, water. The author contributes one of the comparatively few accounts of the flesh of grouse becoming poisonous from the birds having fed on "green laurel."¹

Our author has preserved one of the few actual records of eagles setting their talons so firmly in a large fish as to be unable to withdraw them and thus risk being carried under the water and

drowned. The fish in this case was a 33-pound striped bass, but the eagle was rescued alive. However, both eagles and ospreys have met their fate in this way and so doing, in at least one case, founded an Indian legend. A hunter on a clear lake saw passing beneath his canoe a large muskellunge upon which was riding an eagle, seemingly flying through the water. This apparition, involving creatures of such mighty import in the religion of the tribe, struck terror to the Indian's heart, brave warrior though he was. Rushing back to camp he told the tale and in time it became part of the mythology of his people.

Thus far reference has been made to only a few of the more beguiling passages of "The Market Assistant." The greatest value of the work, of course, lies in its serious portrayal of marketing conditions and in its listing and discussing the great variety of foods that came to the markets in the period 1832-1867. These include not only the domesticated animals and the cultivated fruits and vegetables, but also game, fish, shell-fish, pot-herbs, medicinal and other plants, and nuts. Some of the chapters are small books in themselves, as that on domestic animals, 84, wild animals called game, 83, and fishes, 120 pages, respectively. In the section on fruits there is information of historical value on the varieties in favor at that time and on their origin or introduction. The work is a mine of information also on vernacular names for all the groups considered.

Treating of the sources and abundance of animals on the market, the book is treasure-trove for the student of the depletion of American wildlife. Relating to the group—birds—in which the reviewer is most interested, De Voe comments upon three species now certainly, and a fourth that is probably, extinct. It seems a marvel that this man with whom, through his book, one almost feels well

¹ This subject is discussed at some length in the Proceedings and Transactions of the Nova Scotian Institute of Natural Sciences, Volume 6, 1886, pp. 73-84.

acquainted, should have actually handled birds that are now gone forever. He did not realize that any of them were disappearing. He thought that the heath-hen, which he records as vanished from Long Island and scarce in Pennsylvania, was the same species as the still abundant mid-western prairie chicken. The passenger pigeon was then being brought to the markets in thousands and the author had "often enjoyed the sport of taking the wild pigeon," which he describes. He lists the Labrador duck under the three vernacular names of skunk duck, sand shoal duck and pied duck and terms it a scarce species, seen only in the months of March and October. Those dates would indicate migration of this duck to the southward of New York and are more than is on record elsewhere on the subject. It is a remarkable thing that most extant specimens of the Labrador duck were obtained at markets. Thus in all probability some of the market gunners knew more about the bird than all ornithologists together have known. De Voe wrote as if the species were maintaining its status in 1867, but the last known specimen was collected in 1878. For the Eskimo curlew, the extinction of which few now doubt, our author had no fears. He terms it from the gastronomic point of view as "the best of all the curlews."

Those who have known markets only in recent times, and particularly since passage of the migratory bird treaty act in 1918 which stopped practically all sale of wild birds, can hardly realize the extent to which birds were previously marketed. De Voe in a section on wild fowl includes 33 kinds of ducks, geese and swans besides a grebe and the loon. In another division headed, "Birds Called Game," he treats of 9 native and 4 British birds of the grouse and partridge group, of the European and American woodcocks, 30 native shore birds, 5 species of the coot and rail alliance, 1 tern,

4 herons, the wild pigeon and turtle dove, 2 eagles and 29 small birds, which we almost forget ever had the status of game.

Items of special interest relative to many of these birds reward the attentive reader. As to the trumpeter swan, of which he unmistakably describes "the very lengthy windpipe encased in the breast-bone," he says what probably no living ornithologist would have suspected, namely, that, "this species is not so scarce in our markets as the whistling swan." The latter species under protection has maintained its numbers while the trumpeter is now restricted to small colonies in Montana, Wyoming and British Columbia.

The canvas-back duck apparently gained its high market standing in De Voe's time. He says, "Until very lately, the gunners used to confound these birds with broad-bills, red-heads, and other ducks, and sell them all together. There was no difference in the price. Twenty-five cents would purchase a canvas-back as readily as an ordinary duck. But now . . . the price of a pair of these birds has risen to two and three dollars."

Our author incidentally reveals something of the extent of the traffic in wild fowl in recording that a substantial citizen of Back Bay, Va., employed 20 men to shoot for him and shipped weekly to the New York market an average of from 15 to 25 barrels of ducks and geese.

De Voe's casual remark about avocets, "A few also are found here, brought from Long Island," should stir the curiosity of present-day students, as these birds have only rarely been seen on the Atlantic Coast for many years.

The small "birds called game" listed in this market compendium include some that most of us have heard about in that connection, as the nighthawk, flicker, robin, meadowlark, reed-bird or bobolink, and blackbirds. The group comprises a number of other kinds, however,

now utterly foreign to our conception of food birds, as the purple finch, sea-side finch, cedar bird, catbird, brown thrasher, hermit thrush, Baltimore oriole, blue jay, red-headed woodpecker, cockoos and kingfisher. De Voe even mentions kingfisher and flicker squabs being brought to market.

It must be recorded, to his credit, that our author, though a butcher, did not approve of all this traffic in small birds. Of robins he says, "I . . . think that these birds are more useful to man living than dead." Again of the brown thrasher, he remarks, "Its flesh is delicate, what there is of it; but its live body is *larger* to the farmer, who ought to protect it." Cedar birds, he says, "should never be killed as they destroy more destructive worms than perhaps any bird in existence. In fact all such worm-destroyers should not only be protected by a stringent law, but every person should be so instructed that no law would be required for their protection."

De Voe here grasps the modern philosophy of simultaneous conservation and education. His views on bird protection are further elaborated in the following passage, notably advanced for the time.

In naming the numerous species of game and other birds . . . I do not wish to encourage the

destruction of a single life that would be more useful to the economy of nature than its dead body for the table. In fact, I would go so far as to wish the passage of a United States general law that would especially protect all birds smaller than the quail, except a few shore-birds, or those which are considered and known to be injurious.

Thousands of birds of the small species are wantonly killed merely for the sport, or a few pence. These slaughtered birds, when alive, destroy millions of insects, flies, worms, slugs, etc., penetrating every nook and corner of hedge, thicket, or field; bush and tree, they clear limb after limb, while every passing, folded, or withered leaf is carefully examined and deprived of its concealed but destructive tenant. Without these useful and beautiful little "trespassers," the many destructive insects would increase so rapidly as to become almost a plague, by destroying all fruit and vegetation; while the loss of a little fruit or seed for their subsistence for a short period would amply repay the cultivator for the great services they render him.

It has been particularly noticed that they do not often touch the sound fruit when they can find those that have worms in them. From this fact, they should not be driven from the fruit-trees: they are friends and benefactors, not only to the cultivator but to mankind at large, and to all who have a sentiment for all that is beautiful, poetic, and most musical of nature's productions.

Thomas De Voe's was an early voice urging the value of birds and their national protection. He may with honest pride have called himself Butcher but certainly he had not the soul of a butcher.

THE RISE OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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THE organic act founding the Department of Agriculture directed it "to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word." Hence, throughout its history it has collected, discovered and diffused knowledge about agriculture with increasing effectiveness. The gradual changes in its structure have always reflected basic changes in our national agriculture. The department has been required to respond to public needs as the demands of the public caused Congress to enact new agricultural legislation.

Farming in this country was originally more than a subsistence occupation; it was a way of life. The entire being of the farmer and his family was based upon the farm and all the early distinguished characters of our history were farmers. Indeed practically all of our people were on the soil. But as time passed agriculture became a competitive commercial enterprise. This transformation became possible because of advances made by science and technology. It was not until this change was well under way that we needed a Department of Agriculture. Neither our early American colonies nor their mother countries had ministers of agriculture. The head of each farm family was his own secretary of agriculture.

It is a very far cry from the farmer of 1794, who could produce everything he needed by his own efforts, and the farmer of 1940, who may specialize in producing only one or two commercially marketable

crops, while he depends even for much of his own food upon manufactured products transported to him through long distances. In 1794, for instance, the famous French gourmand, Brillat-Savarin, visited a Connecticut farmer. He tells in his "Physiology of Taste" how he ate a dinner of superb corned beef, a stewed goose, a magnificent leg of mutton, with vegetables of every description, and two huge jugs of cider at each end of the table. Thereafter the happy farmer addressed him thus:

You behold in me, my dear sir, a happy man, if there is one on earth; everything you see around you, and what you have seen at my house, is produced on my farm. These stockings have been knitted by my daughters; my shoes and clothes come from my herds; they, with my garden and my farmyard, supply me with plain and substantial food. The greatest praise of our government is that in Connecticut there are thousands of farmers quite as content as myself, and whose doors, like mine, are never locked. Taxes here scarcely amount to anything, and, as long as they are paid, we can sleep calmly. Congress favors in every way our rising industry; agents from every quarter are always ready to rid us of all that we have to sell; and I have ready-money in hand for a long time, having just sold at \$24 the barrel of flour for which I usually get \$8. . . . I am master in my own house.

That final note indicates that women's rights had not yet been thought of, also that the farmer was his own secretary of agriculture. It was not until farmers got into a commercial economy and began to produce for trade, not merely for home consumption, that they felt the first faint stirrings of need for governmental aid. By the first decade of the nineteenth century an increasing number of farmers began to attempt the difficult operation of producing for sale.

Several other things happened simultaneously then or soon after. Canals and railroads appeared; the telegraph was invented; the British Corn Laws were repealed—inviting the export of American farm products. Farming became a more difficult and complex operation. New plant and animal diseases and new insect pests appeared. When farmers finally wanted government aid badly enough they got it for, as T. V. Smith has often said, a democracy is that form of government in which the individuals or groups who yell loudest get most out of the government.

There are millions in this country today whose ancestors were colonial stock and whose forefathers, generation after generation, enrolled in the army of voluntary resettlement which shoved the frontier from the Alleghenies to the Pacific in little more than a century. This continental sweep of events inevitably produced the need for the great varieties of public service that only a modern department of agriculture could supply.

Even in early days not all American farmers were as happy as the one Brillat-Savarin visited. Some of them worked like slaves and lived a hard and a dangerous life. If they wanted government aid it was mainly in the form of soldiers to combat the manifest tendency of wild Indians to create premature baldness with a scalping knife. But as William Allen White has noted, these farmers had about the same agricultural equipment as Abraham and Lot when they moved into Ur of the Chaldees—the wheel, the lever and cutting tools—though they also had gunpowder, firearms and books which Abraham did not have.

As early as 1770, Benjamin Franklin, then agent for Pennsylvania in Europe, began to send home plants and seeds to be tried out here. Jefferson, our first Secretary of State, was interested also in foreign plant and seed introduction and enlisted the services of our consular staff

to that end. Before that, in 1773, John Adams had introduced resolutions in the Continental Congress proposing that the government encourage the production of certain farm commodities and advocating the establishment of an agricultural society in each colony.

In 1793 the famous Scottish financier and agriculturalist, Sir John Sinclair, founded the first Board of Agriculture in Great Britain. George Washington corresponded with Sir John and in a letter written in 1795 expressed the hope that a national agricultural society would soon be formed here. In his last message to Congress, delivered December 7, 1796, Washington declared that the cultivation of the soil was a proper object of public patronage saying also: "Institutions for promoting it grow up supported by the public purse, and to what object can it be dedicated with greater propriety?"

But no action was taken. American agriculture was still primitive. Farmers worked along with their wood-toothed harrows, their wooden plows with iron points, their hoes, spades, sickles, flails, and little else. Until the age of advancing agricultural technology dawned and got well under way between 1830 and 1850, they felt little need either for elaborate tools or government aid. The more daring of them simply moved on to the ever-progressing frontier as the land wore out where they were.

But some farmers had to remain where they were. Naturally they felt the competition from the rich new lands of the West. For those who went to the new frontier could now produce and ship cheaply back East. Hence the farmers left in the settled eastern rim of the country began to think in terms of government aid to agriculture.

Agricultural societies began to be formed as early as 1785 and by 1831 there were 800 farmers' clubs. Agricultural fairs and expositions became increasingly frequent. The first American

agricultural journal appeared in 1819 and by 1860 there were 40 farm publications. Agricultural education grew from a single chair at Columbia in 1792 to 5 agricultural colleges that sprang up between 1854 and 1860. The federal patent law had been enacted in 1784. Nearly all patents granted in early days concerned agriculture and by 1837 to 1839 the Commissioners of Patents were concerned about the onward march of agricultural technology and how to cope with it.

The American Congress early formed agricultural committees, subsidized silk growing, the culture of sugarcane and the publication of certain agricultural treatises. The Patent Office, then in the Department of State, began in the 1830's quite regularly to collect and distribute new plants and seeds. The first Commissioner of Patents resident in Washington, then a city in the woods, arranged for an agricultural fair which was held in the mall near the present Department building; that was in April, 1805. The first agricultural exposition in the country was held at Union Hotel, Georgetown, in May, 1810; President Madison attended.

The Commissioners of Patents continued to stress the urgency of their needs; they must have aid to cope with demands made upon them by farmers. Meanwhile, on July 4, 1836, the Patent Office assumed its modern form under a new law signed by President Jackson, and its commissioner's first printed report appeared in 1837. Finally, in 1838, President Van Buren, in recommending that the scope of the Sixth Census be increased, induced Congress to grant the Patent Office the legal right to use \$1,000 of its incoming patent fees to collect agricultural statistics and for other agricultural purposes. That money became available in 1839. Agriculture thus got its first aid from the Federal Government.

In 1849 the Department of the Interior

was created and the Patent Office formed part of it, its Section of Agriculture going along. Responding to public demand, President Taylor in 1849 and President Fillmore in 1851 recommended that Congress create government machinery to promote agriculture. From 1830 on the agricultural societies persistently hammered away at this idea until at long last they got what they wanted.

For some time the turmoil over slavery obscured their needs. Furthermore, the Southern delegation to Congress very sincerely believed in the doctrine of states' rights and did not think that the government should aid agriculture. President Buchanan in fact vetoed the first land-grant college act not only because he thought it extravagant but also because he thought the Federal Government lacked constitutional right to provide the aid for the states contemplated by the act—specifically he held that the central government could not give public lands to state governments.

But the need for the department increased as technology advanced, transportation facilities improved, new plant and animal diseases and insect pests appeared, and commercial farming progressed. Finally came the Civil War. The manpower went to the front. It became urgently necessary to produce large quantities of food in the most efficient manner possible. Moreover the Southern delegation no longer sat in Congress. Economic problems further intensified as agriculture became a business, a competitive enterprise. The farmer now formed part of a money economy; he had embarked on the stream of commerce. He must have government sources of information as did the businessmen with whom he had dealings. The government had long given manufacturers and businessmen aid and protection—why not farmers?

Farmers now produced commodities that went floating down canals or spin-

ning away on rails to consumers they never saw. Away went the farmer's stark individualism and his independence of governmental aid. New means of transportation brought western products readily into what had been regarded as exclusive eastern markets. Voluntary efforts of farmers' institutes and societies to teach skill in production methods proved insufficient. The clamor for Federal Government aid was irresistible.

Evidence of this appears in the annual reports of the Commissioners of Patents. In his report for 1861, Commissioner D. P. Holloway made a prolonged plea for the establishment of some institution to serve agriculture. For many years now the Patent Office reports had been devoted predominantly to agricultural matters. Three fourths of our citizens were still on the land, and their pleas could no longer go unheeded.

Why, asked the commissioner, was poor land worth \$100 an acre in New Jersey whereas rich land in Kansas was worth nothing? It was because farmers in New Jersey had customers close by. Agriculture must be aided by industry. Our soil, already far wasted in the East, must be preserved and enriched. Worthless breeds of cattle must be replaced by good cattle. Agricultural tools and implements must be still further improved and rendered more widely available. Hence we should have a Federal Government agency with three bureaus: agricultural, mechanical and commercial.

In his message to Congress of December 2, 1861, President Lincoln sandwiched in an almost offhand recommendation that we might well have in the Federal Government an agricultural and statistical bureau. Naturally more pressing issues tended to occupy his energy at the time, but Congress took heed. It in fact passed three important agricultural laws all of which were duly signed by President Lincoln.

The first signed May 15, 1862, estab-

lished a United States Department of Agriculture with bureau status, broadly defined its functions, and placed a commissioner at its head. The second, signed May 20, provided for apportioning freehold farms of 160 acres each from the public domain to citizens who would make their homes on the land and till it for 5 years. The third, signed July 2, endowed the so-called land-grant colleges with 11,000,000 acres of public land, an area roughly equal to that of Vermont.

The first commissioner of agriculture had previously been in charge of agricultural affairs in the Patent Office. He was a successful farmer and farm manager with the distinguished name of Isaac Newton. In his first report to the President he stressed the necessity for performing scientific experiments to obtain new agricultural knowledge, and for the immediate publication of this information when obtained. The department spent a little less than \$35,000 in the first 6 months of its existence, and much of that went for seed distribution.

Newton said peace must come before agriculture could prosper. Thereafter we should seek an increasing foreign and domestic market for agricultural products; we should have greater respect for labor, a more thorough knowledge of agriculture as an art and as a science, and a more thorough education of our farmers in science and political economy. Whereas farmers had been accustomed to till primitive soils and then move on to new acreages when the soil was exhausted, they must now learn how to make two blades of grass grow where one had grown before.

Above all agriculture must rely on science, "The what and how to do—the concentrated experience of the ages." Applied chemistry would aid us to unveil the mysteries of plants and soils. Nothing was impossible to labor aided by science. Specifically Commissioner Newton said his department would collect,

arrange and publish useful agricultural knowledge; it would collect and introduce valuable plants, animals and seeds; it would answer the inquiries of farmers and be guided by them in its choice of subject-matter for publication; it would test by experiment the use and value of agricultural implements, seeds, soils, animals and fertilizers, undertaking appropriate chemical studies; it would promote botany and chemistry and establish a library and a museum.

Many of these things were done quickly as we shall see later. In his report for 1863 we find Commissioner Newton complaining that the half dozen rooms assigned to his department in the Patent Office basement were much too confining. He also desired better facilities for experimentation with plants. It was true that Reservation No. 2, between 12th and 14th Streets, S.W., now forming part of the department's grounds, had been assigned to him, but the Army had had to take it over as a cattle yard. Ultimately, Commissioner Newton rented two additional rooms in an office building near his own office, and he also got control of Reservation No. 2 which, however, proved inadequate before his death.

For Commissioner Newton died in line of duty June 19, 1867, as a result of sunstroke suffered in July, 1866. He had heard a thunderstorm approaching and had left his office hurriedly to get to a part of the experimental plot a mile away in time to save certain wheat samples from a drenching. While standing in the hot sun supervising this work he suffered sunstroke. The Commissioner was correctly attired in a high silk hat at the time. Washington summer sunshine did the rest.

Horace Capron followed Newton as commissioner and we find him reporting to President U. S. Grant in 1870 on the manner in which he had expended his annual appropriation of \$169,175.24. In this report we find the following interest-

ing paragraph which showed that mere untrained time servers could not do the work of the Department of Agriculture even in 1870.

The department's work demands a higher order of talent than the routine service of most public business; it requires a knowledge of national economy, social science, natural history, applied chemistry, animal and vegetable physiology and practical agriculture; and presents so broad a range of facts in each field of investigation as to demand the most active effort and the most persistent industry. For such labor the most meager compensation is offered, and it is found difficult to obtain an increase of suitable service, and impossible to remunerate properly that already employed which is found to be most efficient and reliable, while that which is practically useless for the purpose is offered in unlimited measure.

Commissioner Capron then asked increased compensation for his employees as did also Commissioner Wm. G. Le Duc 10 years later. It may be said in general that the heads of the Department of Agriculture now resigned, have all been inclined to speak highly of the qualifications and diligence of the employees.

In his report for 1880, Commissioner Le Duc said that the division of chemistry was "now confined to a room in the present building, 20 feet square, with two basement rooms of the same size and a small closet." Hence much important work could not be done. He thought this "national laboratory of a great people" should have better support. The staff then consisted of the chemist and 11 assistants. At that time the Commissioner of Agriculture got \$3,500 a year; the chief clerk, chemist, statistician, entomologist and superintendent of the grounds got \$2,000 each, and the botanist, microscopist, disbursing clerk and superintendent of seed distribution got \$1,800 each.

Farm clamor continued for the department to be raised to full cabinet rank. This reached full intensity just about the time the last of the good public land had been given away and the agricultural frontier was gone. Largely because of

efforts made by the National Grange a bill was passed to the desired effect and on February 9, 1889, Commissioner Norman J. Colman became Secretary of Agriculture. He held this office for 26 days, for the administration changed and Secretary Jeremiah M. Rusk assumed office March 7, 1889. He was the first Secretary of Agriculture by appointment and his first report was dated October 26, 1889. He said the building was very crowded, and then went on:

I found clerks crowded into rooms and subject to discomforts and inconvenience. I have found two branches of two distinct divisions crowded into one small room; records and books lying about upon tables and chairs for want of sufficient wall space to accommodate cases for their proper care and preservation; the chemical laboratory crowded into a damp, illy ventilated and wholly unsuitable basement, originally intended no doubt for storage purposes, and its work in certain investigations restricted because of the offensive fumes from such analyses, and because of the dangers to human life and limb from explosions of gases and other causes; and, in a word, there was a complete want of that systematic and orderly conduct of public business which ought to obtain in every well-conducted office.

At that time not only Great Britain, Germany, France and Russia, but even Brazil devoted far more money to public agricultural services than did the United States. Even then the department received nearly 40,000 letters of inquiry yearly "from all sections of the country, from all classes and conditions." Some thirty million people then depended for their livelihood directly or indirectly upon agriculture. "The correlation of agriculture with other industries of this country" must be carried out, said Secretary Rusk, for the productivity, wealth and prosperity of the farmers governed that of the nation as a whole. Secretary Rusk also began to publish *Farmers' Bulletins* and started a Division of Publications and the giving of agricultural items to the press. He wrote:

Time and expense, ability and experience, lavished on the work of this department can

have no practical results unless we can lay their conclusions promptly before the people who need them.

The department now really became an educational institution. When it assumed cabinet rank the department consisted of the following units:

Division of Statistics; Division of Entomology; Division of Chemistry; Section of Silk Culture; Division of Botany; Section of Vegetable Pathology; Division of Economic Ornithology and Mammalogy; Division of Microscopy; Office of Experiment Stations; Division of Forestry; Division of Gardens, Grounds and Horticulture; Seed Division; Division of Pomology; Folding Room; Library; Museum; and the fully fledged Bureau of Animal Industry created by Congress in 1884. (The Weather Bureau became part of the Department of Agriculture by transfer from the War Department in 1891.)

Meanwhile the continent had been pretty well settled. The era of the open frontier ended formally with the annual report of the Commissioner of Lands for 1890. This closing of the frontier was very significant in determining the growth of public demands for government aid based upon accurate scientific agricultural knowledge. The farmer now had to grit his teeth when the going got tough where he was and make the best of the farming business there. He could no longer move on to rich frontier lands.

Specifically that meant watching carefully the cost of producing each bushel, or pound, or bale of farm products to keep his net return as high as possible. Hence it took reliable scientific information to determine how to reduce the unit cost of production while increasing the net return. This required knowledge about plant and animal diseases and destroying insects, about new and better breeds, varieties and cultural methods.

That knowledge, when applied, acted like ready cash. For it directly increased the per-hour reward of labor by the farmer and his family. Hence it was natural that just around 1890, when the frontier closed, the people should promote their Department of Agriculture to

cabinet rank, increase the appropriations of the department and federal aid to the state agricultural experiment stations as well (as in 1887), and authorize a federal grant of money to the state land-grant colleges, as was done in 1890. By 1896, the Department of Agriculture had 2,497 employees and all were in the classified Civil Service except the Secretary, his private secretary, the Assistant Secretary and the Chief of the Weather Bureau. Its annual appropriation was then \$7,305,637.

We should now look for a moment at the development of the department's individual functions and the growth of its respective units. The first professional employee appointed by the department was a chemist, Charles M. Wetherill; that was in 1862. The department's first scientific research publication was his "Report of the Chemical Analysis of Grapes," which appeared also in 1862. In the seventy-five years that elapsed between 1862 and 1937 there were issued by the department's chemists and soil scientists 8,428 scientific and research reports.

The services of a botanist and a statistician had been required by the agricultural service while in the Patent Office, but Lewis Bollman, statistician, and Townend Glover, entomologist, of the department, were appointed by Commissioner Newton in 1863. A specialist in forestry appeared in 1877, and a Veterinary Division, by special Congressional appropriation of \$10,000 in 1879. A microscopist was appointed in 1871, a special agent to study public roads in 1893, and other specialists as new problems required study.

What later became the Biological Survey got its start as a section of economic ornithology in the Division of Entomology in 1885. In 1893 Congress appropriated \$10,000 for a study of human nutrition and that began in the Office of Experiment Stations. The specific soils

work of the department had its origin in the Weather Bureau in 1893 also. The Bureaus of Chemistry, Soils, Forestry and Plant Industry were created in 1901 and the Bureau of Entomology in 1904. A Bureau of Statistics was created in 1903; 20 years later the Bureau of Agricultural Economics was set up.

Cattle diseases caused increasing concern after the Civil War, contagious pleuropneumonia and what later came to be known as cattle tick fever in particular. There was increasing agitation for Federal aid as the individual states proved incapable of stamping out the diseases themselves. It was as a result of this agitation that the bill to create the Bureau of Animal Industry was introduced in Congress. That bureau controlled contagious pleuropneumonia within 5 years at a total cost of little more than cattlemen were losing annually from the disease in decreased shipments to Great Britain alone.

The bureau later solved the cattle tick fever disease and has now all but wiped it out. It entered in upon a long career of research and regulatory work that has been of inestimable value to the American public in cities as well as on farms. On its staff have worked many who became illustrious in research circles.

As an example of the manner in which certain functions had to be assumed by the department consider the food and drug work. Remember initially that the farmer is essentially a commercial producer who sells at wholesale and who buys at retail. Hence he early needed protection in his capacity as a consumer of products and materials that enabled him to function as a producer. The early chemists of the department therefore studied feeds, fertilizers, soils, plant and grain varieties, cereals.

In the report of the Patent Commissioner for 1844 you will find the chemist had analyzed corn meals and dyspeptics were being assured that only those high

in oil content caused them indigestion! In 1849 the patent commissioner said that the science of food preservation should be studied. In 1868 the Commissioner of Agriculture reported that the chemist had analyzed mineral waters and pharmaceutical preparations and in 1873 he analyzed wines and cereals.

In the report for 1878 we find that the department chemist had analyzed cream puffs, coffee and bologna sausage for suspected poisons and tea and coffee substitutes and adulterants. He had also analyzed baking powder, oleomargarine and a tonic called "Boneset." By 1879 the chemist was making a thorough investigation of butter adulterants. In 1880 the Commissioner of Agriculture explained in his report that the department had no legal control over adulterated foods; this was in blanket reply to many who had written in on the subject. The chemist was then analyzing stock feeds, veterinary remedies, a few patent medicines and even a magic metal polish.

The full names and analyses of these products were published as well as the names of their makers. It was slyly intimated that they were neither worth the price asked for them nor capable of living up to their makers' claims. Soon after 1885, when Harvey W. Wiley became chemist of the department, work on food adulteration began in earnest, spices, condiments, beer, wine, ale, butter and lard being studied earliest. The publication of these studies led to consumer demand for protection. As early as 1883 Commissioner George B. Loring had instituted the study of butter and its adulterations in part, as he said, "to protect consumers against fraud."

The rest is modern history. In June, 1906, the first Food and Drug bill became law after a 30-year battle for its enactment. The Bureau of Chemistry was charged with its enforcement. In 1927, in the interests of efficiency, this regulatory work was separated from the

bureau's research, and was set up independently as the Food, Drug and Insecticide, later merely Food and Drug Administration. In 1940, the new and much more effective Copeland Food, Drug and Cosmetic Law went into full effect. All these things took place as a result of public demand, acting through Congress.

At no time could any honest student of its activities say that the Department of Agriculture had grown by fiat of the bureaucrat. Instead its work had always been authorized by Congress in each instance because groups of citizens wanted something done about something and demanded that the department undertake the job. The history of the department's growth offers the most complete refutation in government of the idea that publicity from within a governmental institution alone determines its growth. The department has undertaken its varied lines of work as citizens discovered the many things they could not do individually or by voluntary cooperative effort.

Commissioner Newton observed in 1863 that farmers lacked time, means and ability to carry on experimental investigations in agriculture, and that isolated individuals could not collect and arrange stores of knowledge for practical use. Hence the department was needed to carry on scientific investigations and its scientific workers wrote glowing chapters in the history of research. They well discharged the trust our people placed in their ability to obtain knowledge that would keep open the doors of the common man's opportunity in agriculture. Much of this knowledge also proved of enormous indirect value in fields remote from agriculture. But in time the collection, discovery and diffusion of knowledge proved insufficient.

First, there was need for some more effective method of diffusion than mere publication. The farmer had to have that ready-cash knowledge quickly to cut costs of production. So about 1900 Dr.

Seaman A. Knapp began to develop his "demonstration-farm" idea, working then in the Bureau of Plant Industry. The plan was to operate farms in different localities where only approved agricultural practices were used. Then all in that locality could come, see the demonstration, and go and do likewise. Meantime the boll weevil had invaded Texas and, at great mass meetings, the Texans began to beseech the Federal Government for aid in routing it. One of the most effective forms this aid took was an extension of Dr. Knapp's idea until literally hundreds of demonstration farms had been established and a new system of adult agricultural education had appeared.

Such importance did this novel idea assume that the General Education Board took notice, regarding it as a signal advance in adult educational methods. The board aided financially, ultimately giving over \$600,000 a year for a while to extend the method in the North and West. The idea changed somewhat after a while. Highly qualified teachers, extension workers, county agents, home demonstration agents, were sent out to instruct the farmers on their farms. The knowledge produced by scientists was thus implemented and found its place in farming and homemaking practice. By enacting the Smith-Lever Bill in 1914 the Congress formally organized this work and the Cooperative Federal-State Extension Services came into existence.

But, as time passed, even that was insufficient. First, our foreign trade dropped off. We were no longer the bread basket and Europe the workshop. From a peak of farm exports in 1898 there was rather a sharp decline until the start of the first World War. The social sciences had to be brought to the aid of the farmer. His marketing and credit problems required study. In the end methods had to be devised to make it

profitable for individual farmers to adopt approved agricultural practices while at the same time planning production to meet demand and conserving the soil and the water supply.

During the first World War and thereafter the position of agriculture became increasingly precarious economically. Vast expansion in acreage cultivated, accompanied by speculative land values, high prices for agricultural commodities, advancing agricultural technology releasing 35 million acres formerly used to feed horses and mules—these factors tended to produce a crisis when our foreign market was suddenly closed soon after the war. At the end of the decade of the twenties, no longer able to sustain our false position as both a creditor and a debtor nation, we shut down on loans to Europe and the inevitable crash followed.

By this time there were essentially four kinds of farmers and all of them had to be considered in attempting to arrive at any solution for the so-called agricultural problem. We had (1) bare subsistence farmers or part-time farmers who just managed to scratch a living out of the soil under the best of conditions; (2) farmers who raised diversified crops and made a fair living because operating scientifically on relatively good soil; (3) highly specialized commercial producers of specific agricultural commodities, the farm factories, and (4) speculators in land and in agricultural commodities.

Agriculturalists now demanded government aid for their industry which was hit harder than any other by the post-war perplexities and uncertainties. The war had reversed the flow of credit. In less than five years Europe owed us huge sums of money which it could only repay by exporting to us. But we shoved up our tariff walls, making this impossible. For a time our loans to Europe sustained the market. But that had to end, then a wave of acute nationalism swept the en-

tire world, we faced increased competition in the foreign market from other sources, and our agricultural export trade declined.

Our century-long trend of producing for an ever-growing export trade thus abruptly ended. But war-time prices had been abnormally high. There had been quick, drastic shifts in land use. Grazing land had been put into cultivation; marginal land had been plowed; forest land had been overgrazed. Grass had been turned under for wheat to win the war. Cash crops had tended to replace grass and forage crops. Soil-binding was forgotten. Agricultural technology increased by leaps and bounds and huge farm factories appeared. Farms sold or were mortgaged for two or three times their former prices and lending agencies made unwise loans to sustain the speculative orgy.

Farmers did their best to make adjustments in the post-war years, but the problem was too big for them. They could not adjust rapidly enough to save their equities. They felt forced to overcrop their land and produce more in the vain effort to meet fixed charges and support their families. Thousands passed annually from owner to tenant status. Millions cried for government aid in readjustment. Others applied directly for relief. The sins of past years rose to haunt us—improper land use, destruction of the soil, water and forest resources, and the exploitation of the forever irreplaceable riches with which nature had endowed us.

All these troubles crashed down upon the farmer. Initially, in the 1920's, farm organizations sought to have a two-price system established that would in part compensate them for the lost foreign market. The Congress passed such legislation, but President Coolidge vetoed it. Later the Congress passed and President Hoover approved legislation setting up the Farm Board to promote cooperative

marketing and stabilize prices. But it failed to stem the tide in part because of the international supply-and-demand situation and in part because it lacked effective control over agricultural production.

The rush of laws beginning in 1933, of which that establishing the Agricultural Adjustment Administration was the first, represented Congressional response to public pressure for solution of these many farm problems mentioned above. The laws aimed to promote soil conservation, water conservation, planned agricultural production, reforestation and the rehabilitation of the underprivileged rural population by education in approved agricultural techniques.

Other laws passed related to the public acquisition and development of land submarginal for agriculture, crop insurance, marketing agreements, tenancy reform, the carrying on of basic research to find new uses for crops subject to periodic surpluses and the increase of farm, forest and water facilities. These new programs were conceived on a basis of broad objectives. They depend primarily and continuously upon scientific research and the widespread diffusion of agricultural information. New agencies had to be established to carry out the wishes of Congress—the Agricultural Adjustment Administration, the Soil Conservation Service, the Farm Security Administration, the Farm Credit Administration, the Rural Electrification Administration, and so on.

All this indicates a broad attack upon the problems confronting the agricultural industry as a whole. The American people are simply seeking to integrate agriculture into the modern commercial economy and to put scientific knowledge to work quickly and efficiently. These functions have been entrusted to the department by the Congress. As one part of its job of carrying out the mandates of Congress, the department has set up one

of the most complete planning programs existing in any government in the world and those plans are based directly on science.

But this is not planning evolved above and enforced below. It is democratic planning. Mere good will among administrators and the provision of legal power and appropriations can not put the adjustment processes to work on individual farms. These farms are owned in fee simple and are tilled under contract or by owners. Therefore the owners and users must decide what will be done on their farms. But they must be enabled to make their decisions in the light of all that agricultural science can tell them about such inexorable factors as soil types, rainfall, degree of soil slope, temperatures and the customs and social habit patterns of the people, locality by locality.

Hence no group of government employees can be wise or competent enough to prescribe exactly how all these public aids to agriculture and the general welfare should be applied. That must in last analysis be settled by the people themselves. But they must act collectively in their communities, counties and states. Hence a natural outcome, in terms of the departmental and other governmental machinery, is the experiment in agricultural planning set up a year or so ago and now swinging into action.

In operating this system the farm people, with technical aid from especially qualified public servants, recommend the application of such public assistance from local, state and federal governments as they feel needed. These recommendations will be brought together state by state and, finally, in so far as they call for federal help, will be considered regionally and nationally. This is essential in a democracy. It is planning from the

bottom up and the top down in which all the people have a hand and a say.

This development is natural and inevitable in the operation of a national agricultural policy governing the activities of the department, since the department itself, in all its varied lines of work, represents merely the democratic response of government to the needs of farmers and of the general population. Hence, you will find a definite continuity in policy of the department, and of its predecessors, from the earliest times of their existence to the present. That is simply because these public agencies have always expressed the response of government to the changing needs of the times in a democracy.

If the various commissioners and secretaries of agriculture had been self-determining promulgators of policies and programs, there would have been, as a matter of course, abrupt shifts and sharp veering changes in course from one administration to the next. As a matter of fact this did not occur. The development of the department's work proceeded as logically and as inevitably in response to the needs of the people voicing their demands as does the growth of a tree in the soil in response to the factors of its environment. The department's growth has been evolutionary, almost biological in nature. It has proliferated naturally, logically and inevitably as a part of the Nation itself. Its present existence in modern streamlined form has made it an invaluable agency in operating the National Defense Program, for it has ready at hand the organization and the machinery to do effectively many tasks which were neglected or were undertaken hastily in emergency set-ups during the World War.

A SKEPTIC AMONG THE SCIENTISTS

By RUFUS SUTER

LIBRARY OF CONGRESS

WE live in the age of science. Everything around us has been influenced by her. This holds not only for the tangible objects like running hot and cold water and the Goodyear blimp lit up by electricity which the Washingtonian sees every summer evening, but also for the things of the spirit: the stories projected on the talking moving-picture screen, radio drama and some modern symphonies.

We have grown too accustomed to the miracles wrought by science to think of her for herself. There was, however, two centuries ago a talented devotee of this pursuit.

David Hume we may not remember. If we do it will be as a jolly Scottish bachelor with whom Madame de Pompadour and other of the colorful ladies in the court of Louis XV enjoyed talking. But we may forget that in his youth he wrote "A Treatise of Human Nature," and a few years later "An Enquiry Concerning Human Understanding." In these works he made some remarks of interest to the student of science.

Hume's significance was not grasped in England in his day. His Treatise, as he said, fell "dead-born from the press," and his Enquiry was hardly less unsuccessful. The difficulty was that his researches lay in an impractical direction out of line with the industrial developments to which science was destined. Strange as it seems when we consider the worldly bent of his mind, he worked among images of the fancy, memories and the sensations: emotions, sounds, tastes, odors, feelings of touch and colors spread out in patterns. It would even

be misleading to speak of him as a psychologist. The psychologist is fascinated by the same objects, but as constituting one subdivision of nature among many: the content of mind as distinguished for example from chemical compounds. Hume's attitude was different. He confined his attention to what we ordinarily call psychical or mental facts because he was convinced that nothing else was known. It is not remarkable that he was unappreciated by his industrial-minded contemporaries.

From our vantage-ground of the twentieth century, however, we may look back at him and see him in relation to the scientific movement as a whole. We will acknowledge that he was in certain respects more acute than the men remembered as inventors of useful machines.

One occasionally wonders why humanity waited so long before having the good sense to observe and experiment. The truth is this wonderment is based upon an illusion. Observations and experiments have been made since time immemorial, but they were piecemeal and barren. We fail to notice them because the issue of modern science has been overwhelmingly rich. What was slow in dawning upon the human mind was the awareness of a fecund principle of direction for search; and why this twilight endured for centuries will be plain when we recall that the aim sought and finally achieved was the unnatural idea of scanning nature for an utterly de-humanized orderliness, that is, a lawfulness or regularity of event not-associated with any quaint human and all too natural conceit.

Once such lines of bare orderliness were unraveled, the question arose: Why do these law-abiding, systematic sequences of happening hold? Galileo's reply is interesting because it is the same as that of any technical student to-day. Forces act in the world (as energy is generated in a gasoline engine); these forces are invisible (as the energy in the motor is invisible), but they are constant, and they cause the regular motions of the parts of nature which we see and touch (as the energy in the engine makes the wheels of the automobile turn).

We wish to emphasize that for science in Galileo's age, as for perhaps most engineers to-day, cause in the sense of unobserved, unobservable, compulsion was all-important.

But now we return to Hume. He made some curious comments about billiard balls in his *Enquiry*. Under these remarks lies hidden an original undertaking: an attempt to discover the nature not of the effects of cause, but of cause *per se*, by observation and experiment. Hume was merely following in the footprints of his great predecessors. Galileo, applying the empirical method to objects sliding down an inclined plane, had decoded the principle according to which bodies fall; Boyle using the same technique had uncovered the rule concerning gases under pressure; Newton had deciphered the law of gravitation. Why should not Hume by an analogous procedure unearth the true character of *causality* about which philosophers had wrangled for generations but without agreement? We will literally observe, then, a case of causation. Thus the billiard ball experiment.

It is unnecessary to be explicit about the result of this investigation. We can guess it in advance. What Hume saw (and what any of us would see, though we were armed with microscopes and

x-ray devices) was that ball A touched ball B and ball B started to move.

This brings us immediately to Hume's premise: Only psychical facts are known. Stated in this bald form his premise seems absurd; but we may restate it: Only observed facts are known. By "observed" is meant "sensed," any by "sensed" being aware through any of the channels of sensible knowledge: sight, hearing, touch, or the like. These two expressions of the premise are equivalent, since what we see are visual sensations, what we hear are auditory sensations, etc.; and sensations are certainly psychical facts. In what else, Hume might ask, can knowledge consist?

Granted this premise, the outcome of the billiard ball experiment is probably irrefutable. If we literally *look* for causation in the sense that Galileo sought for the regularity in the movement of falling bodies, our information will entitle us only to Hume's causal law: A cause is "an object, followed by another, and where all the objects similar to the first are followed by objects similar to the second." This principle is the same in form, and was reached in the same way, as Galileo's generalization that bodies sliding down a smooth, fixed inclined plane move with constant acceleration, which diminishes as the angle of inclination is reduced. The sole difference, aside from subject-matter, is that the former rule is easy of access, while the latter is not evident until the experiment is tried. An analogous statement of Newton's law of gravitation is: Every particle of matter in the universe attracts every other particle, directly as the product of the masses, and indirectly as the square of the distances between them. In none of these rules is recourse had to cause in the sense of invisible force or compulsion.

We will find it amusing to trace briefly some other implications of

Hume's generalization of the empirical method. We may already be persuaded that he was (if an American colloquialism will be pardoned) the original "man from Missouri"; but when we glance at the further steps of his thought we will consider the proverbial Missourian a model of gullibility in comparison with him. Hume did not feel himself justified upon an observational basis in admitting the existence of a substantial world possessing the colors, shapes, smells, etc., exhibited to us by our senses; nor would he acknowledge the existence of minds, souls or persisting self-identical egos, or whatever one wishes to call the agents who have the senses. For Hume reality was a one-dimensional array of observed data. His final position is not unlike that of the Buddhists—a paradox which Thomas Huxley noted many years ago.

It will be worth our while now to catch a bird's-eye view of the Scottish scientist in his setting. There is Galileo who with astonishing insight appreciates that if he assumes the universe to be a machine, and then applies the mechanic's technique of observation and experiment, he will lay bare the regularities of nature. This discovery is followed in rapid succession by the wholesale deciphering of laws. The sciences of mechanics, optics, chemistry, thermodynamics, electro-magnetics, sanitation (to mention only a few) are born. Prediction of natural happenings, and control of nature on a scale never dreamed of by medieval magicians, become really possible. In the end, our industrial civilization with its sky-scrapers and sewers, anesthetics and bombing planes, power-plants and world-wide business organizations come into existence. The picture behind this evolution is, as one would anticipate, practical and severely realistic. The universe consists of tremendous forces. The world is everywhere heavy, powerful, vast, systematic and efficient. It

roars along impervious to human foibles, for the delicate entities of the mind play no part in its construction.

We will notice, however, satyr-like Hume winking at this majestic show with its glowering threat of ultimate reality. He has adopted for his own purposes the observational method of Galileo. He insists that since it has been successful in revealing for the first time in history the uniformities of nature it must be the only legitimate instrument for acquiring knowledge. He directs it, therefore, to the inherited, traditional part of Galileo's thought: the uncriticized faith that the universe is a system of regularly acting forces, of efficient causes (to use the Aristotelian terminology). The natural telescope and microscope of the unaided eye he turns upon these alleged beings, and they vanish into thin air. Only moving patches of color remain. The natural calipers, balances, sound-recording devices, etc., of touch and hearing are enlisted. There is a similar dénouement. If observation is the sole road to truth, and if observation does not reveal matter, energy or mind, these must go along with the other Aristotelian fictions into the limbo of medieval myths. Hume outdid his scientific predecessors and contemporaries, and many of our modern investigators, with their own empirical technique. He turned their instrument against them, and whatever gave tangible body to their ways of thinking, and effectiveness for molding the practical future to their purposes, suddenly loomed without a basis.

Hume alone among the scientists appreciated that the attitude which was to give birth to our industrial, mechanical civilization could lead to results incompatible with at least the emotional background—the feeling of the hugeness and metallic reality of a world independent of human consciousness—which could

form a setting for the growth of that civilization. His quizzical demurrer, however, passed unnoticed, and the scientists continued to observe, experiment and build as if he had never lived.

What was the error in Hume's analysis? None of us is persuaded by his dreamy, ultra-critical Buddhism, yet we can not refute him. Two replies are possible. Either the query begs the question, because there was no error; or there are other ways of knowing besides the senses. The former alternative is not without its champions among the scientists to-day. We have our positivists. The advocates of the latter attitude, however, are in the majority, because this is the viewpoint of common sense for those of us whose intellectual atmosphere emanates by way of the medieval schoolmen from Aristotle. The

supporters of this latter attitude see the world from the same perspective as did Galileo. He was the first of the moderns, but also in so far as he kept faith with the world of matter, efficient causes and souls he was a transmitter of Aristotelian lore.

We often hear of skeptics among religious and ethical thinkers. Hume was that rare creature, a skeptic among the scientists. He is the precedent for our wondering occasionally, while we use our hot and cold running water and listen to our radio, whether it is possible that these and the other miracles wrought by science are after all the issue of an incomplete or baseless piece of reasoning, on the part of our ancestors, misled by the fragments of Aristotelian lore remaining in their minds, in the sixteenth and seventeenth centuries.

OUR FAVORED LAND

In our favored land, as in all lands, "nothing is happy altogether." We occupy, we waste, we suffer, until one day we discover, and report, and at length discuss the common good. The hope arises that with intelligence and spirit we can one day build in America a *Civitas Dei* out of familiar materials. Statistics are needed for that city as well as hope and faith. Carvers and goldsmiths, cedar and fir, oil and grain are the media of the builders. But over and through all is spirit. This is compounded of faith in the good will and the informed judgment of common people; in the search for and the use of our best not our meanest intelligences; in the university's relentless insistence upon excellence; in scorn of those who put cynicism and cleverness above self-sacrifice; in unremitting concern for the poor; in a lively sense of the social responsibilities attached to the privileged life of scholarship. Justice Oliver Wendell Holmes's remark, "I have labored carefully not to mock, lament, and

execrate the actions of men; I have labored to understand them," is a good social text for a university man as for the average citizen.

Some sense of glory there must be too if we would unfix the stars. Here and there must be men of vision who proclaim what America can be: men who cherish the unburied past of heroic deeds and ringing words: ever-remembering men: men flashing the signals of deeds done in high spirit. The university, like the church and the market and the court, must proclaim that only such men are fit for our America. We can foretell that America only if we here and now resolve to make that which we foretell. The land is fit for it if we care for it, our stock is capable, our culture maturing.

O fortunatos nimium sua ei dona norant. ("Oh, only too happy if they could know the advantages they possess.")—*Isaiah Bowman in the symposium, "The University and the Future of America," at Stanford University.*

BOOKS ON SCIENCE FOR LAYMEN

PRESERVATION OF WILDLIFE¹

"WHAT we want is something to shoot at. And we're going to get it if we have to take the old Wyandot rooster out into the woods, turn him loose, and blaze away." This statement, made during recent controversy over quail legislation, represents one segment of the great American public which Dr. Gabrielson serves as director of the Fish and Wildlife Service. The other limit might be symbolized in Cowper's remark that he would not call any man his friend who would needlessly set foot upon a worm.

Between these two extremes, not to forget biological problems and the claims of legitimate economic life, the conservation of animals is no picnic. Throughout this excellent book, it is evident that the author has a wholesome respect for the difficulties of the work to which he is devoting his life. Read thoughtfully, the book is quite as valuable for the insight it gives into the political realities of applied biology as for the scientific information which it contains.

Modestly enough, Dr. Gabrielson announces his purpose in writing the book to be that of putting into simple language some of the basic principles of wildlife conservation. At the outset he emphasizes the fact that all aspects of conservation are but phases of a single problem. He maintains—and demonstrates—that there can be no conservation of wildlife without proper conservation of forests, grassland, soil and water resources. Fundamentally the problem of wildlife production is one of supplying proper environment, with harvest proportioned to reproduction.

In workmanlike fashion the book starts out with a consideration of the cycles of material and energy change which are

the basis of life. One may question the validity of distinguishing between renewable and non-renewable resources, except as a matter of convenience. Nothing is less renewable than an extinct species, while chemical technology may, at any time, place the whole periodic table in the renewable class. For instance, it has been estimated that during the process of extracting bromine from sea-water, millions of dollars worth of other substances have been run through the apparatus in the course of some months. Be that as it may, it is good to see the nitrogen cycle set forth as part of a logical structure instead of being dragged in by the heels.

There follows a consideration of the various types of habitat and environmental factors, a statement of ecological principles and a discussion of various types of wildlife. The book concludes with a presentation of practical obstacles.

Dr. Gabrielson appears to limit the province of ecology more sharply than most students of the field, the reviewer included. With Carpenter he holds it to be the study of living communities and the interrelations within them. Plant ecologists are not likely to concur in his description of unbroken forest as virtually a biological desert. His real point, of course, is sound enough—the greater vertebrate carrying capacity of mixed forest and open country.

In his consideration of various classes of animal life he does not by any means confine himself to those yielding a computable return. Yet he amply demonstrates the economic folly of our present condition. His account of waste in the fur industry is appalling, although it was one of the earliest phases of wildlife to be a subject of legislation.

I gather that, for all our need of basic research upon wildlife problems, Dr. Gabrielson would agree that we know

¹ *Wildlife Conservation*. I. N. Gabrielson. Illustrated. xv + 250 pp. \$3.50. 1941. The Macmillan Company.

enough to do vastly better than we are now doing. In his final chapter he discusses the obstacles to conservation, listing them under three headings: (1) the shortsightedness of the human race; (2) the tendency to seek panaceas rather than real remedies; (3) the lack of knowledge and understanding.

Under these three seemingly vague generalities, Dr. Gabrielson develops a critique of American culture which any one can understand, and yet no one can resent. He says what intelligent men, both radical and conservative, have been saying. But he says it without a hint of the too frequent doctrinaire billingsgate and "class-angled" cant. He obviously thinks and works in the American idiom, and in the tradition of the best branches of our civil service.

Besides being readable, the book has good pictures and a wealth of concrete examples which will be of interest to a wide reading public.

PAUL B. SEARS

EUGENICS AND HUMAN WELFARE

In our modern world, with famine, disease and early death at least potentially under control, men are turning in new directions to control the conditions of human welfare. "The attempt to control the reproductive tendencies of large groups of people, now being crudely essayed in almost every European country, is one of these new fields of activity." These attempts, these new conditions constitute a "preface to eugenics," to a new eugenics program less radical, perhaps less exciting than the one older advocates envisioned, but far more soundly based on present scientific knowledge of the interaction of hereditary and environmental factors, of trends in the size and composition of populations and of sociological and psychological aspects of the environment. Nor is the newer eugenics so radical as to stand

very little chance of being applied or even considered at present.

From this point of view, Mr. Osborn proceeds to consider first the significance of genetic inheritance in man, especially in determining intelligence, mental disease and physical defect, following it with a comprehensive summary of studies of heredity and environment. Here the studies on the Jukes, Kallikaks and Nams receive but passing mention. "They failed to differentiate between the inheritance of bad genes and the effects of a bad environment handed on from one generation to another. As sociological studies they are of interest. As evidence on heredity they are now generally discredited." It is encouraging to find a judgment of this kind from a eugenicist. The more modern studies lead to the general conclusion that "differences in hereditary potentials for intelligence are widely scattered in different family lines throughout the whole population. In order to sort them out with any accuracy, it will be necessary to equalize or allow for environmental conditions affecting the development of intelligence." Doing this would more effectively reduce the proportion of the very dull than increase the proportion of the mentally superior. Consequently, "the eugenics program must take in the whole population, encouraging some couples to have larger families and others to restrict the size of their families."

The next section of the book summarizes our knowledge of population trends and outlines a population policy. Inasmuch as we must look forward to a stable or declining population before many decades, measures to check too great or too rapid a loss in our numbers seem to be imminent. Such measures should take eugenics into account, encouraging large families among those individuals most responsive to our environment, whereas at present the largest families tend to appear under those social and economic conditions that are

least desirable and least favorable to optimum individual development. Differential rates of increase among the various races, regions or socio-economic groups seem of relatively little genetic importance. More to be considered are differences in standards of living and in the capacity to afford children favorable opportunities for development. Extension of birth control to all classes of the population, together with measures to compensate those with large families for the consequent drop in their standards of living, can be included in the steps toward population control. The Swedish system of governmental aid through free services to mothers and children is to be preferred to direct monetary grants to parents, although taxation might be planned so as to help equalize the economic burdens of large family size. This group of measures should promote births in families where they are desired, and it is believed that that will be among those most intelligent and most responsive to their environment. Only in this way can we avoid the eugenic predicament that faces those who would attempt to decide what kinds of persons the future society needs most.

There will be need, too, for altering the western culture pattern of the small family. Various psychological influences might work to that end, in family, school and public service (doctor, minister, nurse, welfare worker). But the radical aspect of the new eugenics lies not in its relation to private life, but rather in its requirement for a change in many existing social and economic forms that produce unequal opportunities for children of different classes and of different-sized families in respect to nutrition, housing, medical care and recreation. Research in many fields is needed to guide eugenic policies undertaking to equalize the environment at a high level.

The eugenic ideal here set forth is truly democratic in character. It lays emphasis on the worth of the individual,

on the right of each to an equality of opportunity during his development. Men are not created genetically equal, but we can tell little about their genetic worth without just opportunities for development. Nor will the socially responsive and intelligent citizen rear the largest families until the "dominance of economics over eugenics," to use Muller's phrase, is considerably mitigated. If democracy is anything more than a static political system, anything worth fighting for to-day, it must be because it includes a vision such as this. The book is very timely.

II. BENTLEY GLASS

UNDERSTANDING INSECTS¹

THIS is a simple little book, so simple in fact that the reviewer's first impulse was to relegate it to a shelf which houses books that might interest the grandchildren, perhaps. We assume, of course, that the latter learn to read before their nascent intellects transcend the level of the textual material in such books. However, "Introducing Insects" is neither a series of bedtime stories nor is it a "Rollo book." I say the last with qualms, but Webster defines Rollo, and our younger readers should know about him even though they never had him inflicted upon them as a steady educational diet.

Professor Needham indicates that his audience is the ordinary citizen. However, as the first figure in the book represents a small boy disgustedly viewing a wormy apple (many entomologists perjure themselves by calling an insect-infested apple "wormy"), I think he had intelligent juveniles in mind; consequently, the book was submitted to a young man of particularly inquiring mind, just past his eleventh birthday. This boy's reactions indicated a considerable and sustained interest. Whether the material may be sufficiently complete

¹ *Introducing Insects*. J. G. Needham. v+129 pp. \$1.50. 1940. Jaques Cattell Press.

for those who regularly follow the advance of science as set forth in the *SCIENTIFIC MONTHLY* is difficult for a professional entomologist to judge. Needless to say there is no misinformation, expressed or implied. Also, the author sticks fast to his promise to refer to the insects only by their common names. Consistency in this respect becomes a little forced here and there, especially in several very uncommon vernacular names coined for certain dragon-flies. However, there is nothing which savors of the pedantic souls who discourse on the "confused" flour-beetle (*Tribolium confusum*) or those who make use of the "suspicious hypholoma" (*Hypholoma suspectum*) for the preparation of mushroom sauce.

There are some eighteen sections to the book, some of them relating to particular kinds of insects like dragon-flies, mosquitoes, bees and caterpillars. Others include references to ecological groups, such as carnivorous insects, those that eat woolens and some others that eat our foods. Finally we are told very concisely how to begin an insect collection and how to rear insects.

One recommendation that should be made is to require the reading of this book by prospective questioners before they inquire of poor overworked college professors how to rid the pet cat of fleas, why the elm-leaf beetle will not destroy their parlor furniture or poison their food, and is he sure that the bugs they describe over the telephone are not termites brought into the house by the neighbor's dog. Many such matters could be settled by reference to Professor Needham's little brochure to the satisfaction of all concerned. This in itself is enough to recommend the book to any one who wants a very brief account of insects that will answer some of the more commonly asked questions.

Finally may I be permitted to quote the very last paragraph in the book. Added as an apparent afterthought, it

is commonplace, but nevertheless not frequently stressed: "Collection-making has been among the early interests of many a great naturalist. Observation of the ways of insects is a source of pleasure to very many people who love Nature, and who find delight in personal knowledge of her infinite resources."

C. T. BRUES

A FREUDIAN TESTAMENT¹

IN the present book Dr. Reik, who has long been associated with Freud, gives us a number of personal glimpses into the life of a great man. Little is added that was not known before, though certain features appear in bolder relief. It is divided into 15 chapters that are not particularly related to each other. They are essays on diverse subjects and what binds them together is that they provide an opportunity to discuss some aspects of Freud's life and personality and of psychoanalysis. The first two chapters recite Reik's personal reminiscences of Freud, while the third and fourth chapters discuss some aspects of teaching and training for psychoanalysis. Chapter 5 records a heretofore unrecorded lecture of Freud's analyzing a "Case of Sudden Conviction." Chapters 6 to 9 are perhaps the most interesting chapters as they deal with Freud as a critic of civilization. The chapter on Dostoyevski is most interesting, and here one is surprised to learn that while Freud admired the artist's rich gifts, he had no great personal liking for him. The last chapters from 10 to 15 discuss a number of unrelated subjects, among which the one on Jewish wit strikes the reviewer as being most interesting.

The book, no doubt, is of interest to trained psychoanalysts, who will find in it much food for reflection although perhaps little that they haven't discussed before. No doubt, too, it will reach the

¹ From *Thirty Years with Freud*. T. Reik. xi+241 pp. \$2.50. 1940. Farrar and Rinehart, Inc.

lay groups for whom seemingly the publishers intended the book primarily. Yet the reviewer wonders whether it is a healthy thing for people professionally untrained in analysis to delve into the subject however interesting material it may contribute to other sciences. Psychoanalysis is and fundamentally remains a branch of clinical medicine that has for its purpose the treatment of certain types of illnesses, and in which the lay public should have no more interest than it ordinarily would in otology or surgical orthopedics. The greatest difficulty that a practising psychoanalyst encounters is among the super-intelligent neurotics who came to the office all-knowing, having read all Freud's works, including the four volumes of *Collected Papers*, and prepared to offer a complete exposition of their neurosis. It soon turns out that such member of the intelligent uses his acquired knowledge as a resistance against treatment and the proofs offered as conscious rationalizations, designed to defeat the analysis. They are the most difficult patients to handle. No one has deplored more than Freud popularization of psychoanalysis, having remarked once: "As science becomes popularized, it becomes degraded."

BEN KARPMAN, M.D.

MEDICINES, NATURAL AND SYNTHETIC¹

OCCASIONALLY a book comes along which is read through at a single sitting, not out of a sense of duty, but because of sheer interest. Very rarely, a book which might be read at a single sitting is found worthy of closer attention. "Magic in a Bottle" belongs in this latter category.

¹ *Magic in a Bottle*. Milton Silverman. xi + 222 pp. \$2.50. March, 1941. The Macmillan Company.

Overlooking the title and the publisher's blurb, which smack a little of the "Ain't Nature Wonderful" era of near-scientific journalism, Dr. Silverman's opus may be given virtually unqualified approval. It comprises ten chapters, devoted to the following: Morphine, quinine, digitalis, cocaine, Ehrlich and the beginnings of chemotherapy, antipyretics, hypnotics, vitamins, hormones and finally the sulfanilamide group. Much of the text is based upon rather unusual literature sources, and even the most arrogant specialist will be entertained in spite of himself.

With regard to the layman, the author succeeds, I think, in giving some conception of the situation of the pioneer, surrounded as he is by a lack of knowledge. He makes it clear, for example, how much more difficult it was to discover the first vitamin than all the rest; how extremely difficult it was to recognize the existence of a diet-deficiency principle. He makes clear exactly what Banting and Best did in isolating insulin that nobody else had quite thought of doing. He is to be commended for remarking that when the Nobel prize went officially to Banting and Macleod, and they divided with Collip and Best: "For one time in history, there was enough honor to go around. . . ."

There is an excellent bibliography and an adequate index. Typography is good, with no apparent errors. The spelling of proper names is done with meticulous care, but why the familiar "Sertürner" should be rendered "Sertuerner" is inexplicable. The text is unbroken by any illustration. It seems that at the very least a cut showing Emil Fischer with a test-tube should have been included. And photographs of modern extraction equipment would have been very much in order.

THOMAS B. GRAVE



From a Portrait by Bjorn P. Njgsk

DR. LEONHARD STEJNEGER, HERPETOLOGIST

HEAD CURATOR OF THE DEPARTMENT OF BIOLOGY OF THE U. S. NATIONAL MUSEUM, WHO CELEBRATED THE 90TH ANNIVERSARY OF HIS BIRTHDAY ON OCTOBER 30. HE IS A MEMBER OF THE NATIONAL ACADEMY OF SCIENCES AND AN HONORARY MEMBER OF MANY FOREIGN SOCIETIES, AND HAS BEEN A MEMBER OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR FIFTY YEARS. IN SPITE OF HIS ADVANCED AGE, HE MAY BE FOUND ANY DAY AT HIS DESK IN THE U. S. NATIONAL MUSEUM ENTHUSIASTICALLY WORKING ON A MONOGRAPH OF THE TURTLES OF THE NEW WORLD.

THE PROGRESS OF SCIENCE

THE AMERICAN ASSOCIATION MEETS IN DALLAS

For the first time in its history the Lone Star State will be host to the American Association for the Advancement of Science, which will hold its one hundred tenth meeting in Dallas from next December 29 to January 3.

Members of the association who have never been in Texas may think as they board the train for the meeting in Dallas that they are starting for a rugged frontier of civilization. It is true that not many decades ago Texas had ranches almost as large as the smaller of the New England states and was famous for its longhorn steers. But science has made it possible for the world to change rapidly, and most rapidly in an undeveloped region of fabulous potential wealth.

Texas has become an empire, and Dallas is one of its great cities with a population of 350,000. It is not only a large city with fine office and public buildings, and finance and industry and commerce, but it has become a center of culture and education. It justly boasts of the fame of its Little Theatre, of its Symphony Orchestra, of the fact that it is the only city west of the Mississippi River on the itinerary of the Metropolitan Opera Company of New York, of its Civic Center group of fine free museums, including the Dallas Museum of Fine Arts and the Dallas Museum of Natural History, of its Civic Federation, of its great State Fair, of its public schools, the Baylor University College of Medicine and the Southern Methodist University, and of its magnificent parks and large lakes, of its seventeen hospitals, of its 300 churches and of its thousands of attractive homes. Practically all this, and much more, has been created since 1900 when Dallas had only 42,000 inhabitants.

In holding its annual meeting in Dallas, the association recognizes the rapid advances science is making in Texas. Dr. Albert F. Blakeslee will deliver on Monday evening, December 29, his address as retiring president of the association on the subject "Individuality in Science." On the following evening, December 30, Dr. Edwin Hubble, a distinguished explorer of the most distant celestial regions with the great 100-inch telescope on Mt. Wilson, California, will deliver the twentieth annual Sigma Xi address on "The Problems of the Expanding Universe." On Wednesday evening Dr. Christian Gauss, of Princeton University, will deliver the seventh annual lecture under the auspices of the United Chapters of Phi Beta Kappa; and on Wednesday afternoon Dr. Rufus B. von Klein Schmid, president of the University of Southern California, will deliver an address under the auspices of the Honor Society of Phi Kappa Phi.

Thus the association, covering essentially the entire fields of the natural and the social sciences and having over 22,000 members, in the address of Dr. Blakeslee will hold its most formal and distinguished session of the year. The Society of the Sigma Xi, with a membership of over 16,000 men and women who have made notable contributions to science, likewise will hold in Dallas its most important meeting in 1941. For more than fifty years students in American universities and colleges have striven for a uniformly high scholastic record in order to become eligible for election to Phi Beta Kappa. The United Chapters of the Phi Beta Kappa, now with more than 80,000 members, will pay their tribute at Dallas to scholarship in science. Honor

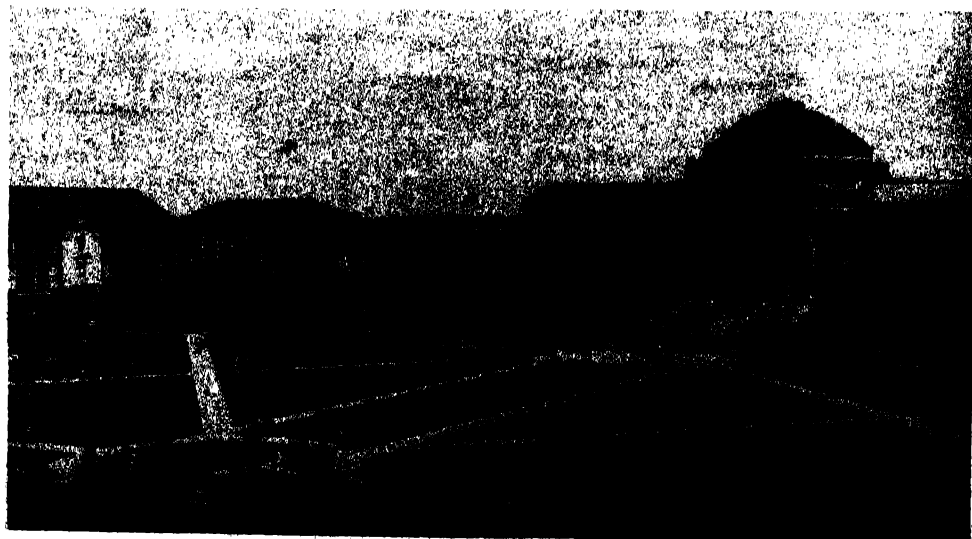
scholars in all fields, through the address of Dr. von KleinSchmid, will recognize the supreme importance of the natural and the social sciences in modern life. In providing these opportunities for scholars from different fields, and with somewhat different primary interests, to meet together, the association serves as an important integrating agency in our complex civilization. These great organizations with large memberships are powerful stabilizing forces in this critical period.

The general addresses which have been listed are only a small fraction of the entire program for the meeting at Dallas. Each of the fifteen sections and the two subsections in medicine through which the association carries on its work will have at least one session for the presentation of papers. The fields of the sections range from mathematics, physics and chemistry through the biological sciences and the social sciences to engineering, the medical sciences and education. The chairman of each of these fifteen sections is a distinguished scientist

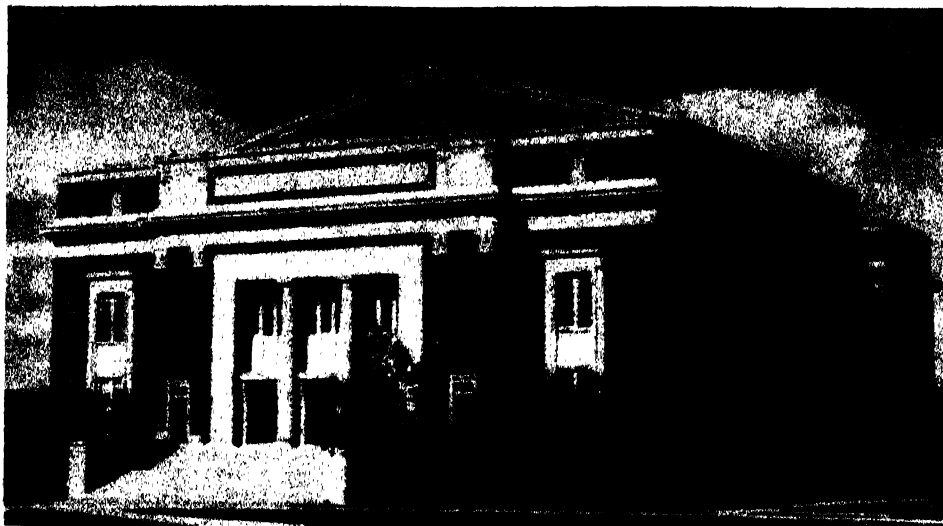
and a vice-president of the association. Each vice-president will deliver an appropriate general address before the section of which he is chairman.

In addition to the fifteen sections and the subsections on dentistry and pharmacy, thirty affiliated and associated societies and several local societies will join with the association in its meeting at Dallas. Altogether there will be about two hundred sessions for the delivery of addresses and the presentation of papers, the number of which will probably be at least fifteen hundred.

Perhaps an idea of the nature of the scientific sessions can be sufficiently illustrated by the programs of the sections on chemistry and medicine. The chemists will hold sessions through three days at which thirty papers will be presented, and will join in a dinner at which the chairman of the section, Dr. George Scatchard, of the Massachusetts Institute of Technology, will deliver his address as retiring vice-president of the association. The first day will be devoted to a symposium on "Biochemistry," in which



THE CENTRAL QUADRANGLE OF SOUTHERN METHODIST UNIVERSITY .
AT THE RIGHT IS DALLAS HALL, WHICH IS THE MEETING HEADQUARTERS FOR SECTIONS IN MATHEMATICS, PSYCHOLOGY AND EDUCATION.



McFARLIN MEMORIAL AUDITORIUM OF SOUTHERN METHODIST UNIVERSITY
WHERE IMPORTANT EVENING LECTURES WILL BE DELIVERED.

eminent specialists will discuss various questions of nutrition, including some of the vitamins. On the second day the program will be on "Spectrographic Analysis," and the third, on "Petroleum Industry," a particularly appropriate subject in the greatest petroleum-producing area in the world.

For nearly ten years the section on the medical sciences has organized symposia on important problems of public health, such as those of cancer, tuberculosis, syphilis, heart diseases and malaria, which have been published by the association. The program of the section at Dallas is on "Relapsing Fever" as it exists among human beings in the United States and in the Canal Zone. Twenty eminent specialists will present papers on this program and it is expected that their contributions will appear as an addition to the series of distinguished volumes the association has published in the field of medical science.

In holding its meeting in Texas, the association is not going to a region without traditions and a long history. More

than four hundred years ago, from 1528 to 1536, Francisco Vázquez de Coronado ascended far up its rivers and crossed its broad plains. The first permanent settlement by white men was established at Isleta, on the Rio Grande River, in 1682. Two years later the Frenchman, Sieur de la Salle, descended the Mississippi River from the Great Lakes and founded a colony on Matagordo Bay. With his murder in 1687 the influence of the Spaniards became supreme and remained dominant until Mexico won its independence from Spain in 1821. On March 2, 1836, Texas revolted from Mexico and became an independent republic—this, its Independence Day, still being a state holiday. Finally, in 1845, the Congress of the United States offered statehood to Texas, which the Texans promptly accepted. In spite of its rather stormy early history, its motto is "Friendship" and, indeed, its name is said to be an Indian word for friendship.

It is difficult to realize the extent of Texas, for its area is four times as great as that of all the New England states



THE HALL OF STATE IN DALLAS
HEADQUARTERS FOR THE ANNUAL STATE FAIRS OF TEXAS.

combined and greater than the combined area of all the states, except New York, that border on the Great Lakes. It rises from low, almost tropical areas along the Gulf of Mexico to the fertile prairies of its central part and to the dry staked plains of the northwest. The cotton of Texas is said to be the most valuable crop grown in any political subdivision in the world; indeed, as valuable as the combined production of all the gold, silver, zinc, lead and copper mines of the United States. Texas produces more petroleum than any other state and its petroleum reserves are fabulous, and its natural gas resources are comparable. It was in this land of variety and abundance that John Neely Bryan, in 1841, built a one-room log cabin and started Dallas on its way.

Fortunately Dallas was at the cross-roads of migrations from the East to the West and from the North to the far

South. It was settled by peoples of various origins and traditions and ambitions. The Spanish influence still lingered, and the French; it was influenced by the old aristocracy of the South, by the industrialists of the Northeast, and by the agriculturalists of the Middle West. Its dreams were influenced by the wide open spaces, and they are being realized. Although it now has big business and is the seat of the Federal Reserve Bank of the eleventh district, it retains the sincere friendliness that has always been characteristic of the American frontier. It is in this interesting region that the association will hold its meeting. And since it is far on the road to Mexico, convenient arrangements are being made for an excursion, for those who desire to take it, to attractive Mexico City and surrounding country.

F. R. MOULTON,
Permanent Secretary

CENTENARY OF THE ROYAL BOTANIC GARDENS AT LONDON

In the eighteenth century a Royal Residence, together with certain houses for accommodation of the Court, clustered round the village of Kew, while a level expanse of alluvial soil on the south banks of the Thames offered a favorable site for horticulture in the country air, then relatively pure. From 1772 onwards, a part of this ground had been used for the cultivation and acclimatization of rare and foreign plants, in which certain ladies of the Court were interested; in particular the Princess Augusta of Saxe-Gotha, wife of Frederick, Prince of Wales. This original botanic garden comprised about eleven acres of ground close to the village of Kew, as it then was. It is represented to-day by an area surrounding the director's office, with entrance to the Royal Gardens, now greatly extended, through the Main Gate from Kew Green.

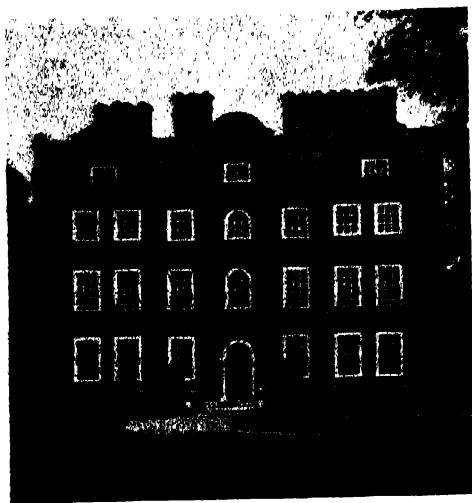
As a private garden the enterprise of 1772 lacked stability. It is true that at times cultivation was active there; but then would follow periods of neglect.

Particularly was this so after 1820, when King George III died. For some twenty years thereafter its fate hung in the balance: some even advocated its abolition as a scientific center. But gradually public opinion asserted itself. In a detailed report to government certain competent authorities sketched out the ideal of an Imperial Botanical Service, of which Kew should be the center. Under that scheme Sir William Hooker, then Regius Professor of Botany in Glasgow, was appointed as director. He took up his duties on April 1, 1841, a date which marks the birth of the modern Kew. For nearly half of the century which followed, the fortunes of Kew were guided by Sir William Hooker and by Sir Joseph, his son, who followed him in the office of director. Both were universally acknowledged as leaders in the botanical world of their time, and they have stamped the work thereafter done at Kew with their own scientific seal.

In 1841 Sir William found the garden to be of very limited acreage, and poorly



THE MAIN ENTRANCE OF THE ROYAL BOTANIC GARDENS ERECTED IN 1845



KEW PALACE, BUILT IN 1681

THE PROPERTY WAS ACQUIRED BY KING GEORGE III IN 1781 AND FOR A TIME WAS USED AS A ROYAL RESIDENCE.

equipped. But his own rich herbarium, museum and library supplied what was needful at the time. The course of the century which followed has shown a steady expansion in the area of the gar-

den, which now extends over more than 300 acres. The plant-houses now include very imposing ranges of glass, while the herbarium, library and museums have been notably increased during recent years; but the Hookerian collections form the foundation of them all. The coordinating center of the whole establishment is the director's office, an inconspicuous brick building towards which the imperial interests in botany converge. Here is the focus of administration of the garden with its numerous staff. From it radiates information and advice not only to those at home, but also to the Dominions and Colonies—and to foreign lands as well; for there is an international free-masonry in science which even war does not wholly paralyze.

It would be easy to expand this brief account of the evolution of the great establishment now known by the name of "Kew Gardens," as a scientific institution. But there is also another aspect of it, by which it is familiar to the teem-



IRIS GARDEN AND MUSEUM II

OPENED IN 1848 BY SIR WILLIAM HOOKER WHO USED THE BUILDING FOR "THE ILLUSTRATION OF ECONOMIC BOTANY."

ing populace of London: viz., as a place of joyful and orderly recreation for holiday crowds. It would be well worth while for any student of human nature to take his own holiday with those crowds,

and to see for himself the various ways in which the dwellers in London enjoy one of the most attractive scenes that the capital of the Empire can present.

F. O. BOWER, F.R.S.

CULTURAL ANTHROPOLOGY SECTION OF THE SMITHSONIAN INSTITUTION'S NEW "INDEX EXHIBIT"

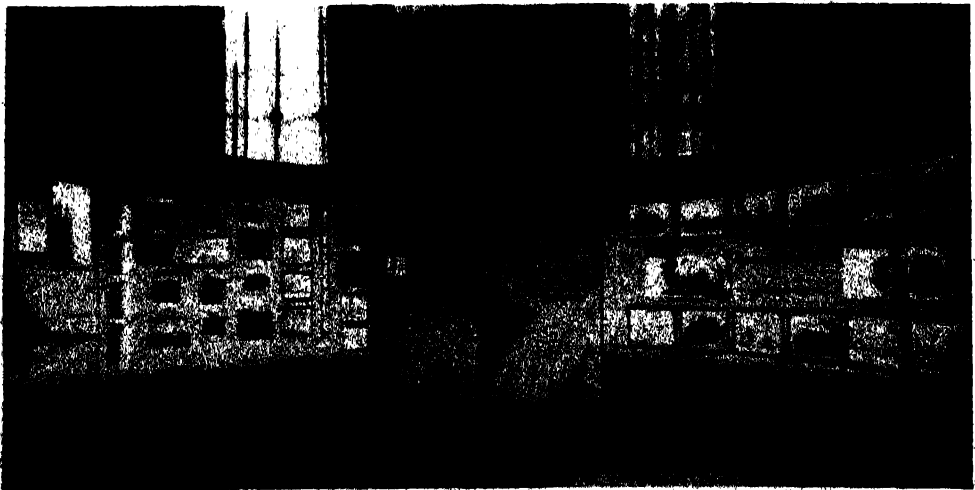
IN the October, 1941, issue of the *SCIENTIFIC MONTHLY* the exhibition of physical anthropology was described. Adjoining this is a semicircular alcove illustrating the research in cultural anthropology. This phase of anthropology studies man's behavior as a social being and seeks to trace the origin, development, and world variation of human activities, such as social institutions, economics, religion, art and language.

That branch of cultural anthropology which studies the cultural remains left by vanished peoples is *Archeology*. The branch devoted to the study of living groups of mankind, especially primitive peoples, is called *Ethnology*. The exhibits displayed in this alcove illustrate, so far as space would permit and in very general terms, the methods used and limited examples of results obtained from

archeological and ethnological research in restricted fields.

These exhibits were prepared by and illustrate the work of the staff in the Department of Anthropology of the U. S. National Museum and the Bureau of American Ethnology.

The left quadrant is devoted to archeology, the study of vanished peoples. On one section of the quadrant is a painting of a cross-section of an Eskimo midden on St. Lawrence Island, Alaska. This painting, together with the actual ivory and bone harpoon heads, illustrates the various changes in shapes and decoration of the harpoons, one element in the Eskimo material culture, over a period of 2,000 years. It also indicates by letters the relative position of the various types as found in the midden from the earliest "Old Bering Sea" type indicated by



CULTURAL ANTHROPOLOGY ALCOVE IN THE "INDEX EXHIBIT"



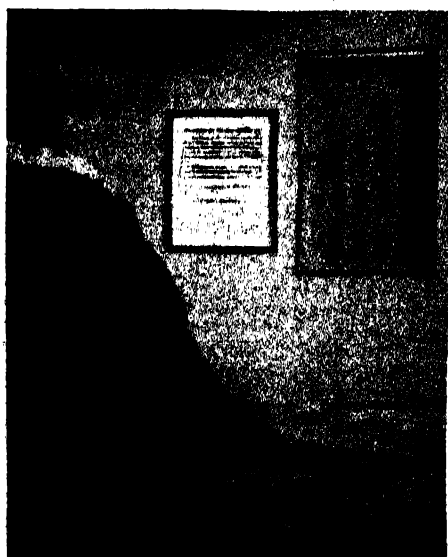
PANEL ILLUSTRATING VARIOUS ACTIVITIES STUDIED BY ETHNOLOGISTS

"A" at the bottom of the midden to the modern type "E" as used by living Eskimo. It is on the basis of such vertical stratification that archeology determines the relative age of bygone cultures.

Between the Eskimo exhibit and the

colored outline map of the western hemisphere are illustrated by means of pottery vessels, photographs of excavated dwellings, charts and sections of wooden beams, the various developmental stages of pueblo pottery, weapons, architecture and clothing from the so-called "Basket-makers" up to modern Pueblos.

Within the past fifteen years over two hundred prehistoric pueblo ruins in Arizona and New Mexico have been dated by a more accurate method than any other systems of chronology dealing with aboriginal remains. This method is based not on stratification, or extinct records such as the hieroglyphics of Egypt, but on the annual growth rings of certain coniferous trees which, under normal conditions, will produce a new growth ring each year. Fortunately the prehistoric people in the Southwest used wooden timbers in constructing their dwellings, and the arid climate was conducive to their preservation. The section of a yellow pine log in the upper right-hand corner of the alcove was cut in 1940, and the center ring dates back to 1898. The cedar roof timber directly beneath the yellow pine log came from Pueblo



VERTICAL STRATIFICATION
IN A PREHISTORIC ESKIMO MIDDEN.

Bonito and has been dated with an outside ring A.D. 1034 \pm 10 and a center ring A.D. 840. The master tree-ring chart—an enlarged example is shown to the left of the beams—carries the present tree-ring chronology from A.D. 1939 back to A.D. 11.

In the center of the alcove is a highly colored map of the western hemisphere on which has been outlined the three varieties of American Indian cultures. These varieties are based largely on an intensive agriculture economy encompassing the American Southwest, Mexico, Central America and the Andean region of South America. Two other types of economy are outlined in color based on a marginal agriculture, and on hunting, fishing, and wild plant gathering.

Within these areas small illustrations depict various scenes typical of the area.

On the quadrant to the right an attempt was made to show the variety of activities usually encompassed by an ethnologist in the study of a primitive tribe of Indians or a group of people. By means of twelve animated water colors are shown examples of the subsistence, dwellings, transportation, clothing, social organization, religion and language of the Sioux Indians living in the northern Plains. In two recessed boxes, well lighted from behind the alcove walls, are displayed a series of musical instruments and colorful examples of the geometric art from the Sioux Indians.

FRANK M. SETZLER

SEED MECHANICS

WITH a world full of seed-carrying agents: birds, fur-bearing animals, wind, water, not to mention man with his ships, trains and other conveyances, it is fascinating to note that in many plant families, outside help was eschewed; and some or all of the members of these families have developed mechanical tensions which assist in the distribution of their seeds.

The prints which accompany this article show only a few of the types of seed pods which eject their own seeds. Not shown here are representatives of the bean family, whose pods twist into spirals to cast out the seeds, touch-me-not, whose pods collapse, phlox, whose pods burst asunder, and witch-hazel and members of the nettle family which develop tension that pinches out the seeds. Nor the Virginia smartweed, which somehow transfers pressure on the extruding style to a point at the base of the seed where this pressure causes the seed to be cast violently away from the plant.

Shown here are wild chervil (*i*), whose seeds are merely swung from the tips of

their wiry stems, and columbine (*b*), whose seeds are swung out of their pods; shepherd's-purse (*c*) whose pods, when ripe, are loosely attached to wiry stems so that any downward pressure will be followed on release by an upward swing that will carry pod, seeds and all up into the air and away on their journey; toothed spurge (*e*) whose seeds are cast away from the plant by a combination of pressure and collapse.

Also shown are some rather more complicated pods. In waterwillow (*a*) the seeds are attached to opposing valves but with their stems crossed so that, when the valves split apart, the seeds are wrenched loose and flung into the air. In pansy violet (*d*) and other violets, the pods first split into three valves and then each valve brings pressure to bear on the enclosed seeds to pinch them out. In toothwort (*f*) and spring-cress, the valves roll up from the base of the pod, carrying some of the seeds with them. In wild geranium (*h*) the individual seeds are held in pockets at the base of the slender style until dry enough for their stems to come



PLANTS HAVING VARIED METHODS FOR SEED DISPERSAL

free and cast the seed over the top of the pod. Finally, and perhaps the most complicated of all, in the wood-sorrels (*g*) the outer seed coat of each seed turns inside out (inside of the columnar pod) with enough pressure to cast away the seed which it previously enclosed.

Examples could be added, perhaps multiplied. But enough have been given to set any mechanically minded observer to thinking, or even to looking at the plant world with new eyes, eyes that never really saw before.

DAVID S. MARX

HEREDITY AND ENVIRONMENT IN THE SONG OF THE CANARY

PROFESSOR MILTON METFESSEL's findings on "The Relationships of Heredity and Environment in Behavior" are significant in relation to current articles on human heredity. These findings are based on six years of intensive experiments on the song of the roller canary. Among his principal findings are the following:

(1) *Heredity*. "Our birds, while still in eggs, were placed in soundproofed cages and were left thus in isolation until the end of the first year of life" (p. 180). "The mature song of rollers consists of tours, of which there are over 20. Tours are somewhat analogous to vowels, consonants and syllables" (p. 181).



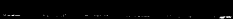
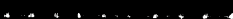




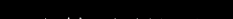
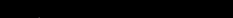
The illustration shows ten types of tours, each designated by a name, with indication of the characteristic rate of pulsation. The flutes are the slowest and the bass rolls, the fastest.

Seven male birds were raised in such isolation that they could not hear the song of their species. The problem was to determine whether under these conditions the birds would develop the songs characteristic of the species. Microphones were installed in the cages, and from the time the eggs were hatched, phonograph recordings of a daily sample of the birds' sounds were made. These records are of permanent character and represent a complete series for each bird. Each of the daily records was transcribed into patterns as in the figure on kymograph paper; then each pulsation was counted, and the number of pulsations per second was computed. The findings are based upon readings of 143,297 separate pulsations which were measured.

Metfessel drew the conclusion that "it was not necessary for a male canary to hear his species song in order to produce

it. The song was a product of his organism. It did not have to be taught, for a canary would learn it by himself" (p. 185). "While the song of the isolated birds resembled that of refined singers of to-day in specific tours, there were other tours which were among those classed by canary fanciers as undesirable" (p. 186). It was believed, from the evidence available, that the song of the isolated birds would be classed as better than that of wild birds and not as good as that of their parents.

(2) *Environment*. Metfessel's next question was, "Can we modify the song of a good mature singer?" To proceed

TOUR NAME	KYMOGRAM	NUMBER PER SECOND
1 FLUTES		3.1
2 GLUCKE		5.0
3 SCHOCKEL		5.8
4 WATER GLUCKE		10.0
5 HOLLOW BELL		12.0
6 DEEP DUBBLING WATER		12.1
7 GLUCKE ROLL		15.5
8 HOLLOW ROLL		16.0
9 WATER ROLL		21.0
10 BASS		25.0
TOURS OF ROLLER CANARY SONG		

KYMOGRAPH RECORDS OF THE 10 MOST IMPORTANT TOURS

ONE SECOND OF EACH TOUR IS SHOWN. AS REPRESENTED HERE, EACH PATTERN IS A COMBINATION OF FREQUENCY, AMPLITUDE AND TIMBRE. A PATTERN (OR PULSATION) IS NOT TO BE CONFUSED WITH THE FUNDAMENTAL FREQUENCIES OF BIRD SONG, WHICH VARY BETWEEN 1,000 CYCLES PER SECOND AND 3,000 CYCLES PER SECOND.

scientifically, he selected one specific aspect which he proposed to modify; namely, the rate of pulsation, which has at least a very close analogy to the vibrato. It had been shown statistically that the typical singers raised in isolation delivered between two and three per cent. of their songs with a pulsation rate of approximately seven per second. To see whether environmental changes would have any influence on this percentage, he put two birds in isolation cages and delivered to them a musical tone of 1,100 vibrations per second with the vibrato at approximately a half step and a rate of seven pulsations per second. The result was that the song of both birds shifted so that the average of cases at that rate rose from two to thirty per cent. "Both birds learned our machine-made vibrato adequately enough to sound like the stimulus tone to our ears" (p. 189). "These two birds not only added the vibrato to their song, but also changed parts of the species song to conform to their environment" (p. 189). "This experiment supplied a cue to the slight differences found in the song of birds of the same species in different localities" (p. 190).

In another experiment, he substituted

a stimulus vibrato of fourteen pulsations for the one of seven pulsations in the preceding experiment. The result of this experiment on four male birds was "Again the expected song of the species was modified by the presence of a specific, stereotyped, tonal environment" (p. 190). Three of the four birds developed a fourteen-pulsation per second vibrato to a significant degree. A similar experiment was made with a vibrato rate of twenty-eight pulsations per second, but this experiment was not completed because one of the males died while it was still in progress.

"Thus, it appears that the organism of a bird can supply both the elements of a song, and a particular combination of elements which can be identified as species song. A specific tonal environment can supply new elements, modify those supplied by the organism alone, and give a new combination of elements" (p. 192).

The author points to a number of biological and sociological implications. To the reviewer, the most significant aspect of these experiments lies in the furnishing of objective data for a biological theory of the vibrato. The interested reader should turn to the original article.

CARL E. SEASHORE

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